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GENERAL ELECTRIC Review

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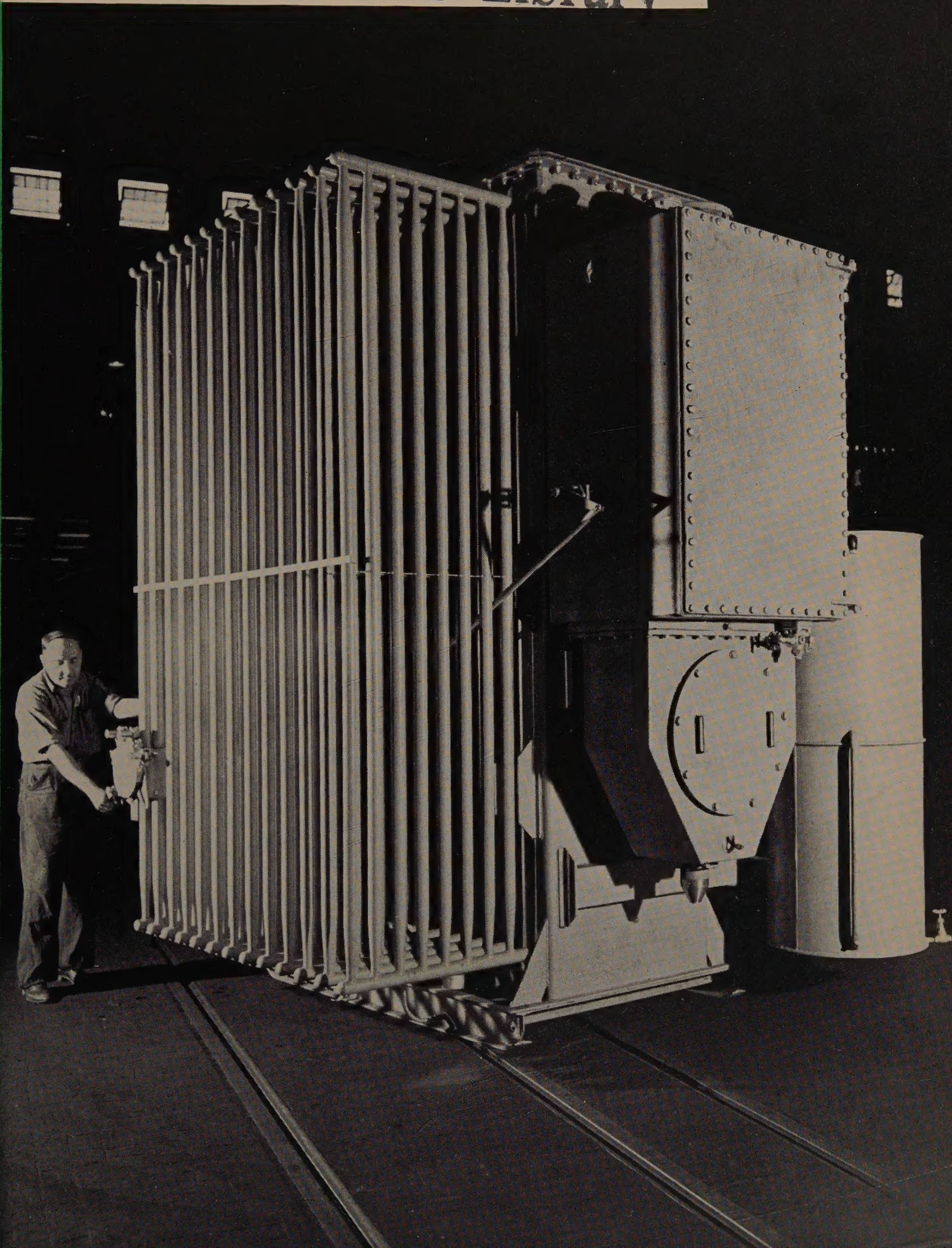

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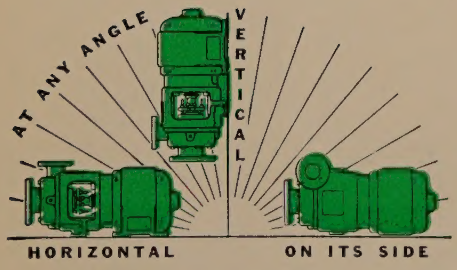

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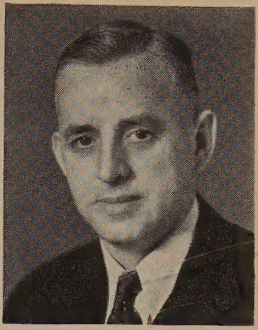
IESTS THAT DISTINGUISH TYPES OF LUBRICATING GREASES

Vhen rolling-contact bearings are to be used in services where unusually igh or low temperatures are encountered, it is essential to know that he grease with which they are packed is suitable for the application. Ainute samples are adequate to identify various approved greases



H A McConville

By H. A. McCONVILLE
Schenectady Works Laboratory, General Electric Company

DURING the past few years the grease industry has made enormous strides in developing new ypes of greases, some to meet specific applications and thers to operate under conditions for which no ordiiary petroleum-base grease has been found suitable.

The new greases include those made from synthetic liesters and the silicones. Some of them have been ised at bearing temperatures up to 400 F and others at emperatures as low as −67 F. They have been so uccessful that they have been made commercially vailable. Some have been approved under Govern-nent specifications, such as an AN-G-25 and 14-G-8; nd their use is required in aeronautical apparatus.

As builders of that type of apparatus and also as nanufacturers of electrical equipment which may be ubjected to extremes of temperature, on either the igh or the low side, we have been keenly interested in nethods that would distinguish between various types f grease. Such methods are especially needed when louble-shielded bearings are bought packed with low-emperature grease. If apparatus is to work success-ully at either very high or very low temperatures, its earings must have the proper grease in them; and in a louble-shielded bearing no trace of the grease is ordi-arily visible to aid in its identification.

The first low-temperature greases used during the ast war were of the petroleum type, and consisted of a ithium soap combined with a mineral oil of low viscosity. hese greases were fairly satisfactory as long as hey were used *only* in low-temperature service but if he apparatus was ever required to run at temperatures f 160 F or over, the light ends of the oil were volatil-zed off and the grease lost its good low-temperature roperties.

Many users of bearings had in stock a quantity of he shielded types packed with these older varieties of rease of the AN-G-3a type and it was necessary to ake sure that none of these bearings became mixed ith those containing the newer, synthetic diester or ilicone types of grease. A method of determining hich of these greases a bearing contained was there-ore needed. Furthermore, it was desirable that the ethod would not require the removal of the shields rom the sides of the bearings, in order that the bearings ight be used later in apparatus production.

These requirements would seem to pose a problem impossible to solve. However, the methods described in this article were finally developed by works laboratories of our company. The method devised at Schenectady is in continual use and 10 percent of all the ball or needle bearings received and said to be packed with low-temperature grease are tested by that works laboratory before being released for production. By this testing we have detected bearings packed with a wrong grease before the apparatus was assembled, thus avoiding costly disassembling later to determine why the equipment would not operate successfully at low temperatures.

One method of identifying some of the low-temperature types of grease was devised by A. E. Baker of the Thomson Laboratory of the Lynn River Works. That method will distinguish a grease made with a synthetic diester, one with a synthetic diester and petroleum oil, and a straight petroleum oil grease. As probably no two grease companies making mixtures of diesters and petroleum oils use the same proportions, it should be possible with further work to utilize this method to identify any one of the five greases approved under specification AN-G-25.

THOMSON LABORATORY METHOD

Weigh out 0.2±0.001 gram of grease on the tip of a small glass rod. (Any suitable fixture may be used to hold the rod while weighing.) The weighing may be done on a good analytical balance. Transfer the rod and grease to a small test tube, taking care to prevent smearing the grease on the sides of the tube. Add 10 cc of 95 percent ethyl alcohol and heat slowly to boiling, but do not boil. Allow the solution to stand for about three hours, and then titrate with distilled water until the alcoholic solution becomes slightly turbid or cloudy. A microburette with 0.05-cc graduations is recommended for this application.

Depending on the type of grease being tested, its alcoholic solution will tolerate the addition of different amounts of distilled water before becoming cloudy. The sebacate diester greases will permit the largest addition of water, and the petroleum oil—diester mixtures and the straight petroleum oil greases permit successively smaller amounts.

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Based on the results of that test, various types of greases can be identified as follows:

Type of Grease	*Water Toleration in 10 cc of Solution*
Diester	2.1 – 2.25 cc
Diester—Petroleum	0.8 – 1.0 cc
Petroleum	0.50 – 0.52 cc

Where it is possible to obtain a grease sample as large as 0.2 gram, this method gives very reliable results.

When the bearings to be examined are so very small that it is possible to obtain only a smear of grease without removing the shields, the following procedure is used by the Schenectady Works Laboratory.

SCHENECTADY WORKS LABORATORY METHOD

Initial consideration is given to the readily distinguishable characteristics of various low-temperature greases. For instance, while the color will vary between different manufacturers' greases all the way from almost white to a yellow tan or medium tan, an analyst who is familiar with various manufacturers' greases can fairly well identify a type of grease by color.

Also, when the first low-temperature greases were approved under specification AN-G-3a, all contained lithium soaps; and to establish that a grease was of that type, it was then sufficient to prove the presence of lithium, along with showing that the grease was of light consistency and would thin down readily when rubbed in the palm of the hand.

With the advent of the synthetic diester greases and silicones, all using lithium soaps, the identification of lithium is only one part of the necessary procedure.

For identifying synthetic diester greases of the sebacate type in the Schenectady Works Laboratory, use is made of a procedure developed by R. B. McBride of the Lubricants Section. It is based on the difference in odor given off by petroleum oil and by synthetic diesters when heated in the presence of sodium hydroxide.

The method is suitable for use with either open or certain types of double-shielded bearings, and has been successfully applied with bearings as small as R2. Bearings of the sealed-for-life type, however, have such close-fitting shields that, unless rotating the bearing causes enough grease to escape to provide a sufficient sample for test, the only recourse is to remove one of the shields to procure the necessary sample.

To apply the flame-test and the odor-test methods, first carefully unwrap the bearings and lay them on a clean white surface. Avoid exposing them to possible contamination any longer than necessary. Cut a sheet of ordinary sulphite writing paper into narrow strips, the width depending on the size of the bearings to be tested. For R2 or R3 bearings, the paper width should be about 1/16 in.; for larger bearings it can be wider.

If the bearing is of the open type, the end of a platinum wire can be dipped directly into the grease to procure test samples. If the bearing is double shielded, slip a narrow strip of paper at an angle between the inner race and the side shield and work it around inside until grease adheres to the paper, then remove it, and smear some on the platinum wire.

The flame test is then made by holding the platinum wire in the oxidizing flame of a Bunsen burner and noting the flame color. The detection of lithium as the principal metal is one of the signs that the grease is of the low-temperature type.

Lithium imparts to the flame a bright carmine red which appears quickly and is unmistakable in color. (It is not necessary to first form a chloride, by dipping in hydrochloric acid, as would be done in testing for calcium.) Sometimes sodium is present, and if so it imparts so strong a yellow color that the lithium color may be masked. For such a condition, a special filter glass is used to exclude the sodium rays. The glass recommended is No. 5120 Didymium filter glass made by the Corning Glass Works. If only lithium (or lithium and sodium) is present, the flame will appear brilliant red when viewed through this filter and that color will persist for a long time. If the sample being tested also contains a calcium soap, the flame color will be purple.

The next step is to determine whether the grease contains a petroleum oil or a synthetic diester. The procedure makes use of odors, a criterion that under ordinary circumstances might not be considered very scientific. In this application, however, the differences are readily apparent.

Using metal tongs, a pellet of sodium hydroxide is dropped on a hot-plate that has been heated to the temperature at which that hydroxide melts. When the pellet has melted, a strip of paper with the smear of grease on the end is touched to the liquid sodium hydroxide. If the grease was made from ordinary petroleum oil, the odor given off is that of ordinary burnt oil. If the grease contains a synthetic diester, however, the sodium hydroxide liberates the sodium salt of the dibasic acid and an alcohol, and gives off an odor that is unmistakable and characteristic of this grease. One of the greases approved under AN-G-25 has a composition that is slightly different from the others and when this grease comes in contact with the sodium hydroxide a sweet odor of burnt glycerine is detected. The silicone greases when touched to the melted sodium hydroxide set up as a solid white mass, which action definitely identifies them.

CONCLUSION

By the methods described in this article, it is readily possible to determine with certainty whether a grease under consideration is a mixture of petroleum oil and soap, of a synthetic diester and soap, or of a silicone oil and soap. The methods do not distinguish between the various diester greases, but one such grease that is slightly different in composition from the others can be identified. These simple and inexpensive procedures have been found very useful in checking bearings for factory production.

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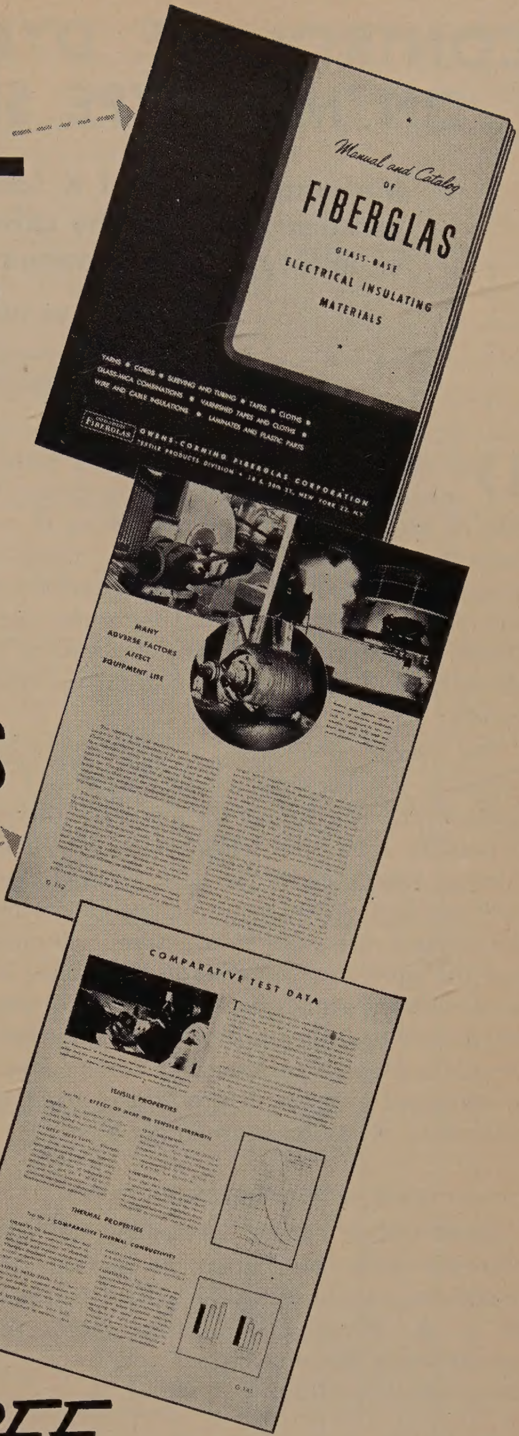
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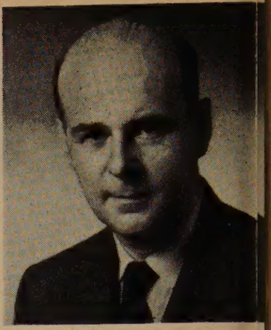
CONTROL OF DYNAMIC BRAKING ON MILL-TYPE SERIES MOTORS



Midrange values of K factors furnish a reliable, practical basis for the calculation of performance of mill-type series motors in hoisting operations

By G. W. HEUMANN
Control Engineering Divisions, Apparatus Department
General Electric Company

D-C SERIES motors have found wide use with cranes and similar hoisting equipment the operation of which includes the restraining of overhauling loads during the process of lowering by means of dynamic braking. Reliability of controller performance for a line of motors produced for this purpose can be determined with a practical degree of accuracy by the use of midrange K factors derived from the characteristic curves.

The power circuit used for this operation is illustrated in a generalized manner in Fig. 1. The series field and the armature of the motor are there connected in parallel. A block of resistance R_F, which includes the internal resistance of the field, is connected in series with the field. A block of resistance R_A, which includes the internal resistance of armature, commutating field, and the equivalent brush-drop resistance, is shown in series with the armature. A third block of resistance R_S, which includes the resistance of the power leads between the point of constant line voltage and the motor, is connected in series with both the armature and the series field. Resistances are in per unit.

CALCULATION OF PERFORMANCE CURVES

Speed-torque curves, describing the performance obtained with this circuit for various amounts of resistance, can be calculated by a method presented by A. A. Merrill.(1) Expressing motor performance quantities in per unit, speed and torque can be calculated by the following formulas:

$$S = E/K \qquad (1)$$

$$T = KI_A \qquad (2)$$

where

S = Speed in per unit of rated motor speed

T = Torque in per unit of rated motor torque

E = Emf in per unit of normal generated motor emf at rated torque and rated speed

I_A = Armature current in per unit of rated motor full-load current

K = A factor, expressed in per unit, which is a function of motor field and armature currents.

Factor K is the equivalent of the commonly used terms "torque per ampere" and "volts per rpm." Its numerical values are determined from motor test data. Factor K is affected by the air-gap flux. Since armature reaction affects the magnitude of the flux, K must be expressed as a function of field current and armature current.(2) For an analysis of motor performance, currents and voltages are calculated in the various branches of the motor circuit.(3) When motor emf, field current, and armature current are known for each assumed operating point, speed and torque can be calculated by Formulas (1) and (2).

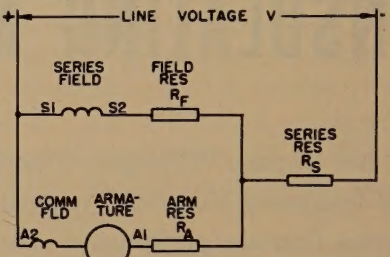


Fig. 1. Generalized dynamic-braking power-circuit connections

Formula (2) for the calculation of torque is rigorously correct only when T is the internal developed torque of the motor and K is determined on the same basis. The torque delivered at the shaft differs from the developed torque by the amount of the losses. Since it is not possible to measure developed torque directly, and since the output torque at the motor shaft is of interest to control design and application engineers, the question arises as to whether the use of Formulas (1) and (2), employing K factors determined by measuring motor-shaft output, will yield sufficiently accurate results. A study(4) has shown that the method here described of calculating speed-torque curves with K factors of a specific motor obtains a deviation of actual speed of ±0.03 per unit from calculated speed.

Numerical values of K are not apparent from the design data as customarily published in motor handbooks. K factors include secondary effects in the magnetic circuit such as saturation and armature reaction, and considerable variations in K factors exist between

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This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—Editor

(1) Numbered references are listed at the end of the article.

motors of various types and sizes. In the past, insufficient data have been available to generalize K factors for a whole line of motors, and speed-torque curve calculations had to be based on data available for individual motors, with no assurance as to the general validity of the calculated curves.

Most frequently used for crane-hoist work are the so-called "mill-type" series motors, as exemplified by the General Electric line of MD-600 frame motors. Experimental K-factor curves of all the motors of this line have been taken. Accurate speed-torque curves for a specific job, using a specific motor, can be calculated with the help of such curves, which are available upon request to designers of controllers for such motors.

Since calculating speed-torque curves for each motor of the line would be a laborious process, the question arises whether it would not be possible to develop a generalized set of K-factor curves allowing the control designer to calculate speed-torque curves for various motor circuits which would be reasonably accurate for the whole line.

CHARACTERISTICS OF THE MOTORS

The motors are generally so selected for application to crane hoists that the horsepower required for hoisting full load at rated speed does not exceed the 30-minute rating of the motor. This, however, may be modified, because of duty-cycle requirements, where motors of different time rating than 30 minutes are needed to prevent overheating of the motor. In such comparatively rare cases it is possible to calculate speed-torque curves for the 30-minute rating of the motor and then convert the results in terms of the motor rating actually used for the application. Since most calculations are made for 30-minute-rated motors, the data given in this article are based on the 30-minute ratings. Base values for per-unit calculations of motor performance are listed in Table I.

The data are based on standard motor ratings at 230 volts. Horsepower ratings and base speeds are taken from the motor handbook. Base torque is calculated from rated horsepower and speed. Base voltage is normal emf, or 230 volts minus the IR drop of the motor at rated load. Base resistance is base voltage divided by rated full-load current.

TABLE I

BASE VALUES FOR PER-UNIT CALCULATIONS OF MOTOR PERFORMANCE

Frame Size	30-minute Rating (Hp)	Base Speed (Rpm)	Base Torque (Lb-ft)	Base Voltage (Volts)	Base Resistance (Ohms)
602	10	690	79.7	173.2	3.90
604	19	600	174	191.0	2.51
606	33	510	356	196.0	1.52
608	45	470	526	199.2	1.16
610	65	450	795	201.6	0.82
612	100	433	1270	204.7	0.55
614	135	400	1855	204.8	0.41
616	200	405	2715	208.6	0.286
618	265	382	3820	210.4	0.22

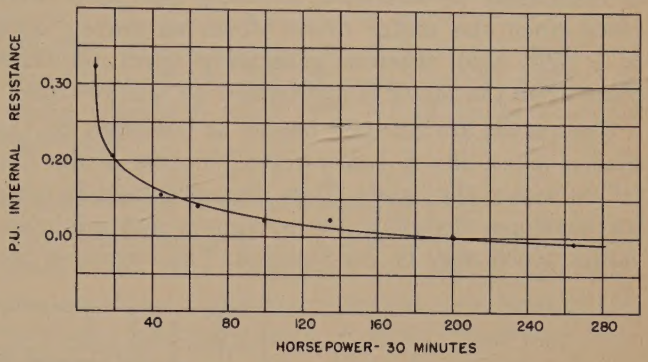

Fig. 2. Internal resistance of the series motors

Since resistances R_F and R_A in FIG. 1 include the internal motor resistance, it is necessary to know the motor resistance in order to determine the external resistance required to realize a calculated speed-torque curve. In FIG. 2 internal resistance in per unit is plotted versus the 30-minute motor horsepower rating. As a reasonable generalization, two thirds of the total resistance is in the armature and commutating field, and one third in the series field.

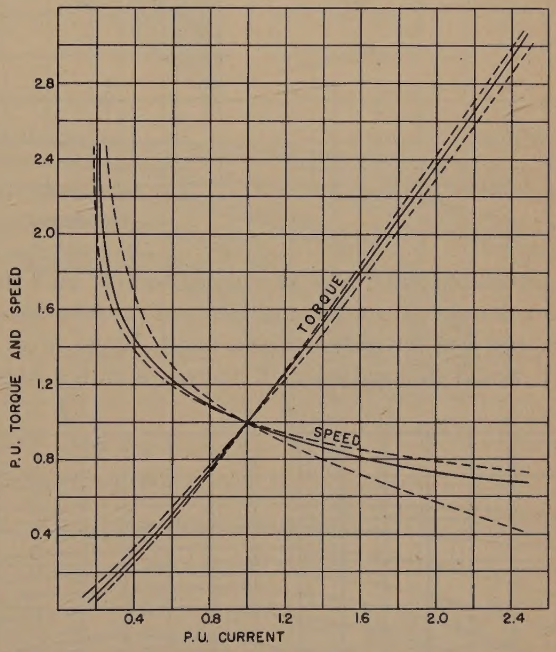

Fig. 3. The average speed and torque versus current characteristics

External characteristics in terms of torque and speed versus current are plotted in FIG. 3. The solid curves are average curves, and the broken curves designate the range within which individual motors may fall. In general it can be said that, because of variances in internal resistance, the droop in speed at higher currents is greater than average with small motors, and smaller than average with large motors.

GENERALIZED *K* CURVES

Per-unit values of *K* were obtained from test data for all motors of this line. They are plotted in FIG. 4 as a function of field current and armature current, for both motoring and generating operation. In terms of crane-hoist performance, motoring operation takes place when the motor drives down an empty hook or a light load, whereas generating operation takes place when the motor is overhauled by a heavy load.

The curves are actually bands, as indicated by the shaded areas, the *K* factors of all motors of the line falling within the bands. Thus, the solid lines forming the envelopes designate the maximum and minimum values which may be encountered. The envelopes are not associated with any particular motor, and the *K* factors of a specific motor may vary at random between the upper and lower limits of a band. There is no rule which would tie location of *K* factors within a band to the motor size; the *K* factors of a specific motor frame may fall anywhere within a band.

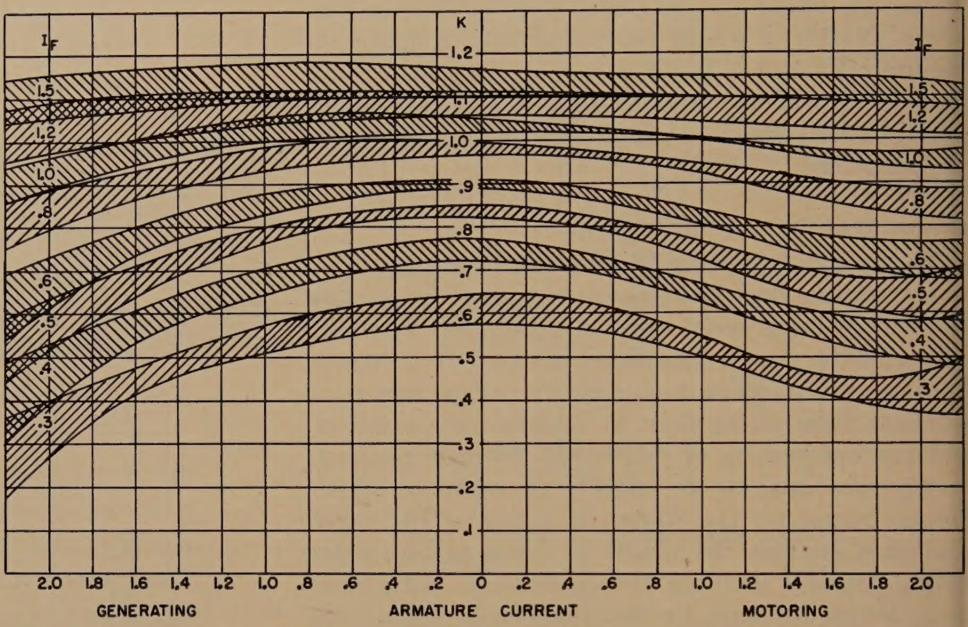

Fig. 4. Composite K curves for the motors

For calculating speed-torque curves, the midrange value of *K* has been chosen rather than the average or mean value. Choosing the midrange value for calculations means that the deviation of the actual speed-torque curve of any motor of the line from the calculated speed-torque curve will be minimum, and the possible deviations will be divided evenly between above and below the calculated curves.

Midrange *K* curves for the motors of the line are plotted in FIG. 5. In order to obtain a measure of the deviations of actual values of *K* from the midrange values, the actual *K* factors of all motors of the line were read and compared with the midrange values for certain assumed field and armature currents. The results of this comparison are plotted in FIG. 6. The base line is marked off in deviations from the midrange

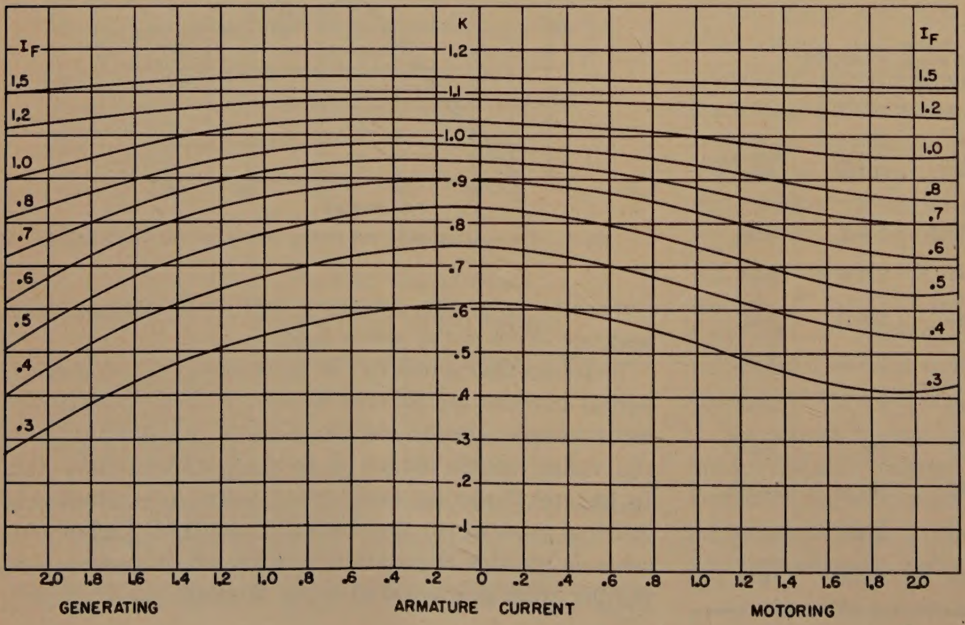

Fig. 5. Midrange values of K curves

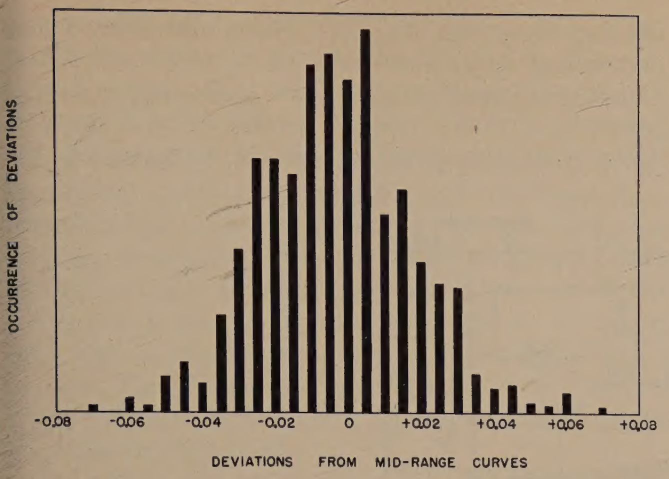

Fig. 6. Deviations of K factors from midrange curves, according to Fig. 5

curves, at intervals of 0.005 per unit. The vertical bars represent the relative occurrence of the deviations, rounded off to the nearest 0.005. The bars form a normal distribution pattern.

By far the greatest number of deviations fall in a ±0.03 band. Since the method of calculation yields an inherent tolerance of ±0.03, the rms tolerance is 0.042*. This means that when the midrange K curves are used for calculating speed-torque curves, all except a small fraction of a percent of actual speed points of all motors of the line will fall inside a band of ±0.042 of the calculated speeds.

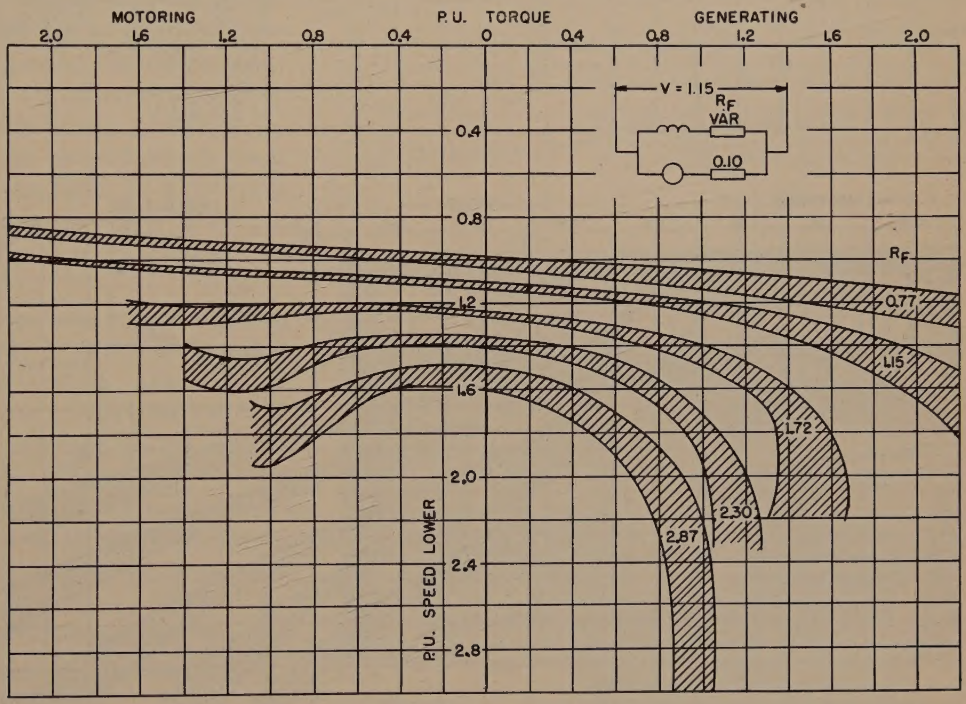

Fig. 7. Speed-torque curves, lowering, for no series-resistance condition

According to Fig. 6, a comparably small number of deviations fall outside this tolerance, the maximum deviations being ±0.07. These larger deviations are associated with armature currents in the range of 1½ to 2 times normal, which are somewhat beyond the normal operating range of the motor. The rms tolerance under this condition is ±0.075.

Allowing for stray errors in the calculations and slight differences in motors of the same type, the following statement appears to be in order: When midrange K curves are used for calculating speed-torque curves for this particular line of series motors, deviation of actual motor speed from the calculated speed-torque curves will not exceed ±0.05 within the normal operating range and ±0.10 under overload conditions.

APPLICATION TO CRANE-CONTROLLER ANALYSIS

To substantiate such a statement, speed-torque curves have been calculated for several dynamic-braking circuits which are typical of those used on the high-speed lowering points of actual crane-hoist controllers. High-speed connections have been chosen because they involve low field currents and high armature currents, resulting in greatest variation in K factors. For these calculations, the results of which are presented in Figs. 7, 8, and 9, it has been assumed that the motor has an internal resistance of 0.15, which corresponds to a popular motor rating for general-purpose cranes. Assuming a distribution voltage of 230 volts, the per-unit line voltage is 1.15.

Selection of resistance values for the motor-circuit branches has been based on the following considerations: Varying field resistance R_F has a pronounced effect on motor speed, and all practical crane controllers are based on the principle of obtaining lowering-speed changes by field weakening. Armature resistance R_A has no effect on the no-load speed, but increasing R_A increases the slope of the speed-torque curves—that is, the variation in speed between no load and full load. Armature resistance R_A is generally kept as low as practicable, and for the present calculations only internal resistance is included, with no external resistance in the armature circuit.

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*Statistical method of analyzing tolerances indicates that, if a system contains several tolerances, the combined tolerance of the system can be taken as the square root of the sum of the squares of the individual tolerances.

Series resistance R_S has a minor effect on no-load speed, but it greatly affects the slope of the speed-torque curves and the stability limit. Increasing the hook load, which corresponds to increasing overhauling torque on the motor shaft, increases armature current; this in turn increases armature reaction. Because of the consequent reduction in air-gap flux, each circuit setup is associated with a torque maximum beyond which the motor is not capable of restraining an overhauling torque. Examination of FIG. 5 shows that, for any give amount of field current, factor K decreases with increasing armature current. Thus, in the region of highe currents, a point is reached beyond which K decrease faster than the armature current increases, so tha increased armature current results in decreased torque. The maximum torque thus obtained is the stability limit; if the hook load is increased beyond that point, control of the load is lost and overspeeding results.

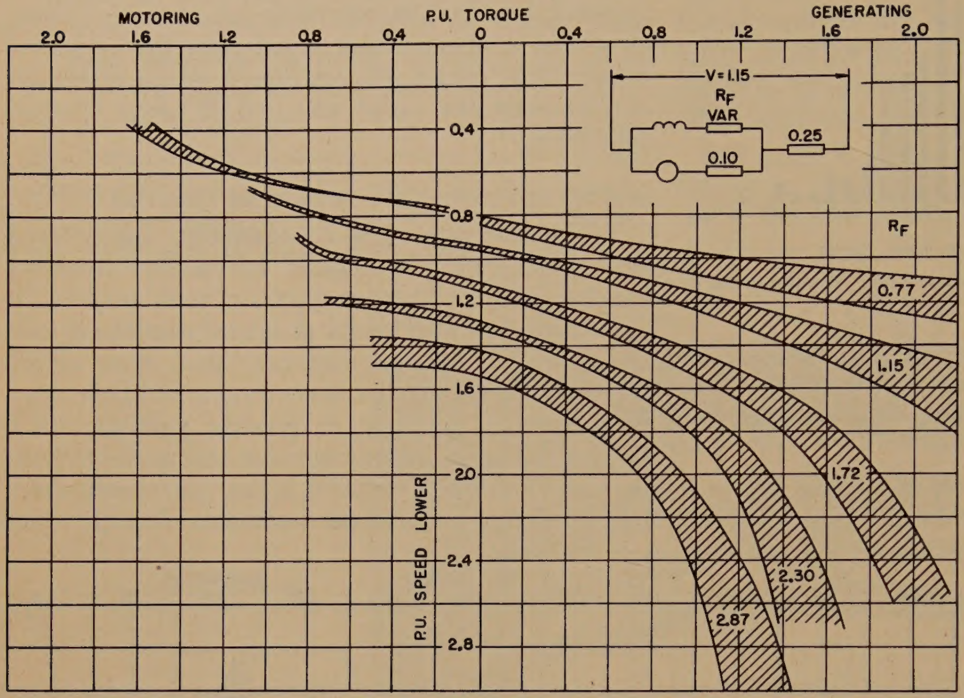

Fig. 8. Speed-torque curves, lowering, for series resistance of 0.25 per unit

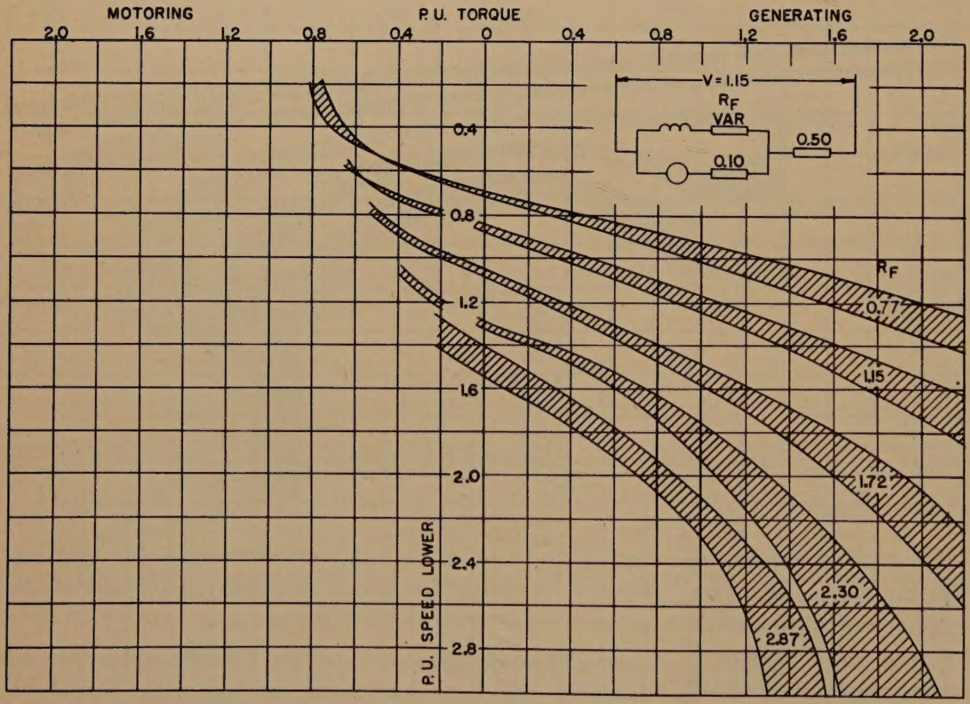

Fig. 9. Speed-torque curves, lowering, for series resistance of 0.50 per unit

Stability limit is a function of field current. The more the field current is reduced, the lower the stability limit becomes. Series resistance R_S affects the distribution of current between the armature and the field-circuit branches. It causes an increase in field current with increasing load, thereby increasing the stability limit.

In FIG. 7 speed-torque curves are plotted for a circuit containing variable amounts of field resistance R_F—corresponding to field currents of 1.5, 1.0, 0.67, 0.5, and 0.4 respectively—and no series resistance. Each curve is actually a band, enveloped by two curves calculated with the maximum and minimum K factors from FIG. 4 for each condition of field and armature current. Thus, calculated speed-torque curves for any of the motors in the line being considered will fall within the cross-hatched bands.

To evaluate the curves in terms of actual crane performance, it is necessary to correlate the motor torque and the hook load. The overhauling torque exerted by full hook load on the motor shaft equals the motor torque required for hoisting full load, multiplied by the square of the mechanical efficiency of the hoist.

Ordinary general-purpose cranes have mechanical efficiencies close to 85 percent. Assuming that rated motor torque is required to hoist full hook load, the overhauling torque on the motor shaft, exerted by full hook load being lowered, would be 0.7. Allowing an aggregate safety margin of 100 percent for torque peaks due to acceleration and elasticity in the ropes; for low-voltage condition on the power lines, which would reduce the stability limit; and for possible carelessness of the operator in overloading the hook, it is desirable to so design the dynamic-braking circuit as to obtain a stability limit of not less than approximately 1.4 motor torque, generating.

If the K factor were a function only of field current, the speed-torque curves of FIG. 7 would be straight lines with no limit on motor torque. Actually the curves are far from straight lines, and the stability limit becomes dangerously low when the field resistance is increased beyond 1.72, or, in other words, if field current is weakened below two-thirds of normal current. By comparison, the curves of FIGS. 8 and 9 illustrate how the addition of series resistance substantially increases the stability limit. With $R_S=0.25$, the field resistance may be increased to 2.30; with $R_S=0.50$, the field resistance may be increased to 2.87 with adequate margin in stability limit.

Examination of the speed-torque curves shows that the crane-hoist-control designer is not free to specify the no-load and full-load lowering speeds of a controller at will. Lowering speeds of a crane which is neither under- nor over-motored should not exceed approximately 1.5 at no load and 2.0 at full load on the hook, thereby insuring adequate margin with respect to the stability limit. Speed-torque curves must have slope, because of the inclusion of series resistance in the controller design.

ACCURACY OF CALCULATED RESULTS

Using midrange K factors according to FIG. 5 for the calculation of speed and torque obtains curves which are midway between curves calculated with maximum and minimum K factors according to FIG. 4. An examination of the band-widths of the curves in FIGS. 7, 8, and 9 shows that, between no load and full load, the spread in speed for given values of torque is less than ±0.03 for field resistances up to 2.30, and less than ±0.06 for a field resistance of 2.87.

Since it has previously been stated that the method of calculation may involve an inherent deviation of ±0.03, the total deviation of the motor speed from calculated midrange curves will be less than ±0.05 for low and moderate lowering speeds, and less than ±0.10 for high lowering speed. Stability-limit torque values in FIGS. 7, 8, and 9 deviate not more than ±0.10 from the midrange values. The prediction made in connection with the range in K factors for this line of motors has thus been substantiated.

In conclusion it may be stated that, if controller performance is calculated by using the midrange K factors, all motors of the line will follow the calculated performance with an accuracy which is reasonably close for practical purposes.

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Meter Scale	—20 VU to +3 VU and 0 to 100%. Type A has VU reading on upper scale. Type B has percentage reading on upper scale. Scale is large, clearly marked and carefully designed to minimize eye fatigue.
Indicating Meter	NAB Standard; 4-inch square, rectifier type possessing ideal characteristics for monitoring purposes.
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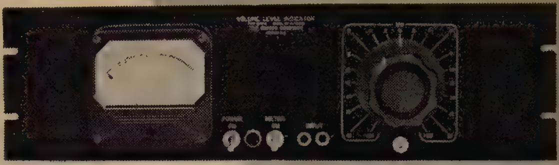
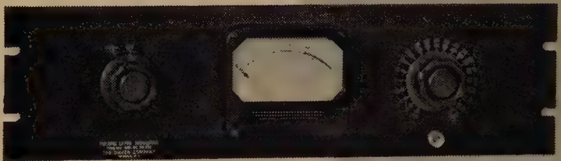
Finish	Standard, black alumilite panel. Other colors available upon request.



Type 920
Rack model, low-level bridging type. Meter multiplier range: —20 VU to +20 VU. Power supply, 100—130 V, 60 cycle AC, with voltage regulator for normal variations. Reference level: 1 mv into 600 ohms. Special ranges on request.



Type 915
Rack model, terminating and bridging type. Meter multiplier ranges: Terminating, —6 VU to +32 VU; bridging +4 VU to +42 VU; or terminating, —6 VU to +16 VU; bridging, +4 VU to +26 VU. 2 VU steps. Reference level; 1 mv into 600 ohms

Type 910
Rack model has same characteristics as Type 911. Available with illuminated scale, if desired.

Type 911
Portable model, bridging type. Meter multiplier is a constant impedance "T" network which extends the range of the instrument in steps of 2 VU from +4 VU to +42 VU or +4 VU to +26 VU. Reference level: 1 mv into 600 ohms.

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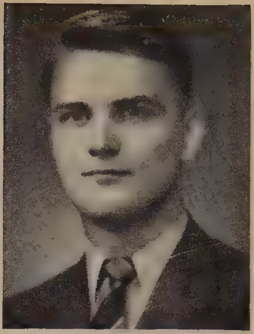
AUTOMATIC EQUIPMENT AND TECHNIQUES FOR FIELD MAPPING

The application of new automatic equipment for the purpose of speeding up the solution of the many engineering problems which require the accurate plotting of steady-state fields

By J. K. MICKELSEN
General Engineering and Consulting Laboratory
General Electric Company



J. K. Mickelsen

ACCURATE flux plotting of steady-state fields in one-tenth the time necessary by hand is made possible by the automatic field-mapping machine (FIG. 1). Tracing of equipotential or flux lines is fully automatic. Plots are obtained by simulating the desired field with an electric field in an electrolytic tank and utilizing an electronic control (servo-mechanism) which automatically locates and traces the equipotential lines. Shallow tanks with flat bottoms are used to simulate two-dimensional fields. Three-dimensional fields having one axis of symmetry may be plotted by using a tank with a sloping bottom. In both types it is possible to simulate appropriate physical constants such as permeability, thermal resistivity, dielectric constant, etc.

Fields such as electrostatic, magnetostatic, thermal conduction, and potential flow of fluids, satisfying Laplace's equation* can be flux-plotted. Fields such as the torsional stress in shafts of constant cross section, or the velocity distribution of viscous fluids flowing in pipes, which obey Poisson's equation† can also be plotted.

The number of fields defined by the equations of Laplace and Poisson is endless. Problems which have been solved by use of the automatic field mapping machine include:

(1). The magnetic field distribution of a cyclotron magnet
(2). Temperature distribution between tubes of a heat exchanger with heat transfer by conduction
(3). The electric field in the cross section of a wave guide
(4). The electric field of a cable test terminal.

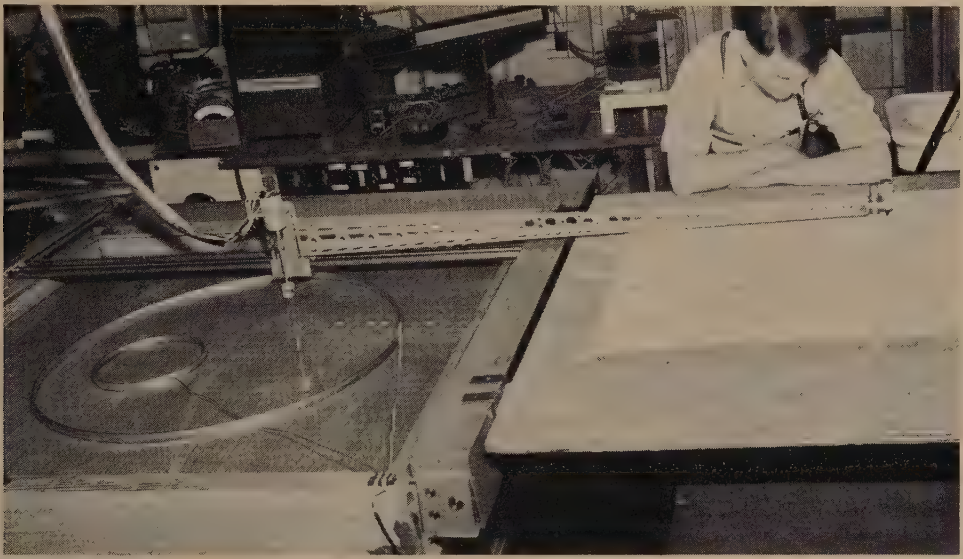


Fig. 1. As the automatic field-mapping machine traverses the field simulated in the electrolytic tank which is at the left, a plot is made by the stylus shown at the right

Information can be obtained on such factors as the inductance, capacitance, and mutual coupling for various conductor configurations or the characteristic impedance of transmission lines. Fringing effects and leakage flux, or the variation in magnetic field strength for a changing air gap can be investigated. Other problems for which the machine is useful are the trajectory of electrons in an electron gun or the stress concentration of a shaft in torsion.

Laplacian fields may be simulated in the tank by simple boundaries—usually copper strips when equipotential surfaces are represented. Fields defined by the more general Poisson's equation require a special

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This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

* See Equation (4).
† See Equation (6).

technique but may be simulated by close, evenly spaced wires acting as current sources.

The value of these maps lies in the information which can be derived. Data can be obtained from the spacing, curvature, or shape of the lines.

Once set up, the machine can be operated without highly skilled personnel. Selection of appropriate techniques and interpretation of results, however, require a higher degree of technical training.

PRINCIPLES OF OPERATION

The field to be mapped is simulated in the tank by an electric field acting in an electrolytic solution. Voltage is applied to the conducting boundaries; then, by tracing the equipotential lines, the flux plot is obtained.

Field Equations of the Electrolytic Tank

The field equations of the electrolytic tank for steady-state conditions can be derived as follows: First, consider a volume element of the electrolyte (FIG. 2). If there is no current source present, the sum of the currents passing through the sides of the volume element must be zero. Therefore

$$(di_x/dx)+(di_y/dy)+(di_z/dz)=0=\nabla\cdot\mathbf{i} \qquad (1)$$

where $\mathbf{i}$ is the current-density vector and x, y, and z are the rectangular Cartesian co-ordinates.

The electric-field strength vector $\mathbf{E}$ has the same direction as the current-density vector, with its magnitude proportional to the magnitude of the current density. Thus mathematically we have $\mathbf{E}=\rho\mathbf{i}$ (2) where ρ is the resistivity of the electrolyte.

The electric potential ϕ is defined by $\nabla\phi=-\mathbf{E}$ (3) Combining Equations (1), (2), and (3), operating by ∇ (in a dot product), for constant ρ, we get

$$\nabla^2\phi=0=(d^2\phi/dx^2)+(d^2\phi/dy^2)+(d^2\phi/dz^2) \qquad (4)$$

If, in certain portions of the electrolytic solutions, there is a distributed current source, Equation (1) becomes

$$\nabla\cdot\mathbf{i}=\mathrm{d}J/\mathrm{d}x\,\mathrm{d}y\,\mathrm{d}z=I \qquad (5)$$

where dJ is the current added in the differential volume dx dy dz.

Combining Equations (2), (3), and (5), operating by ∇, for constant ρ and I, gives

$$\nabla^2\phi=-\rho I \qquad (6)$$

Equation (6) is the Poisson equation; the Laplace equation, Equation (4), is the special case where $I=0$.

In the two-dimensional situation, with the field having no variations in the z direction, Equations (6) and (4) become

$$(d^2\phi/dx^2)+(d^2\phi/dy^2)=-\rho I \qquad (7)$$

and

$$(d^2\phi/dx^2)+(d^2\phi/dy^2)=0 \qquad (8)$$

Equation (7) postulates a uniformly distributed current source. This distributed source can be approximated, as has been mentioned, by wires inserted in the electrolyte; the wires carry equal currents and are closely, evenly spaced.

Equation (6), when expressed in cylindrical co-ordinates, becomes

$$(1/r)(d/dr)(rd\phi/dr)+(1/r^2)(d^2\phi/d\theta^2)+(d^2\theta/dz^2)=-\rho I \qquad (9)$$

For the case of circular symmetry, it is seen that there is no variation with θ. Thus the Poisson and Laplace equations can be expressed as

$$(1/r)(d/dr)(rd\phi/dr)+(d^2\phi/dz^2)=-\rho I \qquad (10)$$

and

$$(1/r)(d/dr)(rd\phi/dr)+(d^2\phi/dz^2)=0 \qquad (11)$$

The use of a tank with a sloping bottom for simulating a three-dimensional field having one axis of circular symmetry can be explained as follows: From geometrical symmetry, the field map formed by the intersection of equipotential and flux surfaces with the r-z plane, $\phi=K$, is seen to be the same for all planes passing through the z axis. Therefore, all r-z planes are flux or equipotential surfaces. In most cases they are flux surfaces and can be simulated by insulating boundaries in an electrolytic tank. In this equipment the sloping bottom of the tank forms one such boundary and the air above the water is the other nonconducting medium. The "shore line" formed by the upper water surface against the tank bottom corresponds to the z axis of the simulated field.

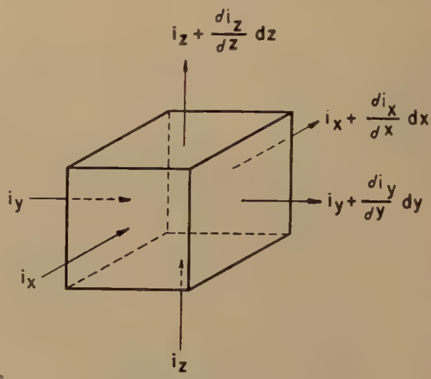


Fig. 2. Volume element of the electrolyte

For this three-dimensional problem, a technique similar to the one described for the two-dimensional problem can be used for simulating fields that obey the Poisson equation.

Techniques for Simulating Fields

In the ideal case, the equipotential surfaces should be simulated by the surfaces of perfectly conducting materials. The flux surfaces should be simulated by the surfaces of perfectly insulating materials. Experience in using tap water as an electrolyte has shown that copper satisfactorily simulates an equipotential surface and that varnished wood and Cerese wax are suitable insulating media.

The question may be raised, "Does the automatic field-mapping machine plot only the equipotential lines of the simulated field? Can't it be used to plot the flux lines also?"

Fortunately, it can simulate both, although the machine draws only the equipotential lines in the tank. By proper choice of boundaries, these equipotentials in the electrolyte will correspond to either the flux or the equipotential lines of the simulated field. For example, the electric-field distribution in the cross-section plane of a radio-frequency transmission line is shown in FIG. 3. This indicates the two arrangements of insulating and conducting boundaries that simulate the equipotential and flux lines of the electric field of the transmission line, here a line having a cylindrical conductor inside a square tubular conductor.

Although the over-all field distribution of a transmission line or a wave guide is not given by Laplace's or Poisson's equation but by Maxwell's equations, in some cases the field distribution in a cross-section plane at any instant is given by the Laplace equation.

Variations in the appropriate physical constants of the media of the simulated field can be accounted for in the electrolytic tank. One such case was the problem of finding the electric field in a rectangular wave guide, including the effect of the dielectric supporting the internal conductor, as shown in the upper section of FIG. 4. The upper left-hand quarter of the field is simulated in the lower section of FIG. 4. The greater dielectric constant of the internal conductor support is simulated by an increased depth of water, the ratio of the depths being equal to the ratio of the respective dielectric constants of the simulated media. The copper pins, short pieces of 40-mil diameter, are added to aid in simulating the abrupt change of dielectric constant.

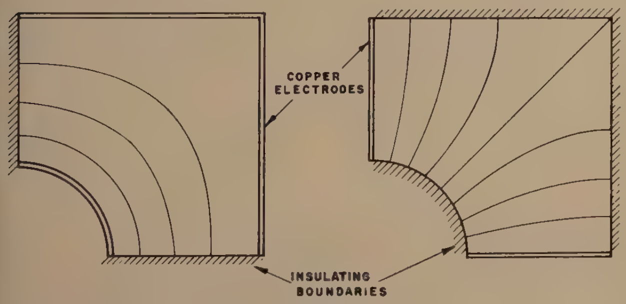


Fig. 3. Simulations of the electric equipotential (left) and flux (right) lines of a radio-frequency transmission line

The usefulness of the automatic field-mapping machine is greatly increased by its ability to make flux plots of fields obeying the Poisson equation. FIG. 5 sketches a typical problem, a splined shaft under torsion. (Note that because of symmetry only a small portion of the field needs to be mapped.) The surface of the shaft is simulated by a copper electrode formed to the same shape. The copper pins, which are evenly spaced, have their voltages adjusted until they carry equal currents. The stresses in the shaft can be calculated from the spacing of the equipotential lines.

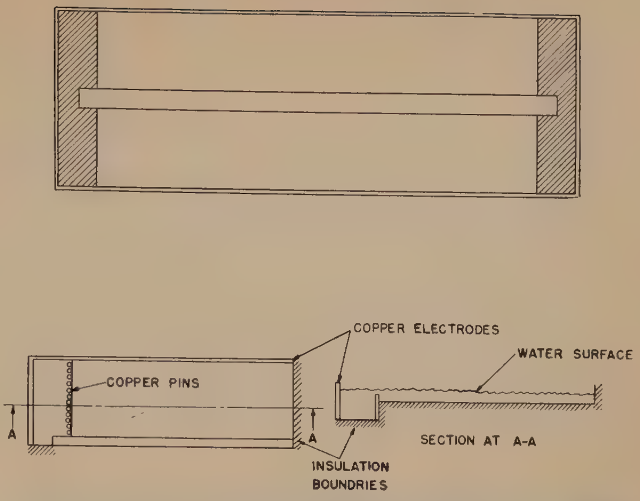


Fig. 4. Wave guide (top) with dielectric material supporting the center conductor, and (bottom) a simulation of that wave guide

Since the velocity distribution of a viscous field flowing in a pipe is also given by Poisson's equation, the equipotential lines of a field map made as indicated in FIG. 5 will correspond to the fluid velocity profiles. FIG. 5 could also be interpreted as giving the temperature distribution in the cross-section plane of a current-carrying conductor (thus having heat generated within it by I^2R losses) whose outer surface is an isothermal.

One observation should be noted: both the Laplace and Poisson equations deal with scalar potentials. However, the magnetic potential in a current-carrying region is a vector potential. Very similar to Poisson's equation is the equation governing the flux distribution within the current-carrying region

$$\nabla^2\mathbf{A} = -4\pi\mathbf{i} \qquad (12)$$

where **A** is the vector magnetic potential and **i** is the current-density vector. The vector magnetic potential is commonly defined by

$$\mathbf{B} = \nabla\times\mathbf{A} \qquad (13)$$

where **B** is the flux-density vector. At present there appears to be no technique by which Equation (12) can be simulated in an electrolytic tank.

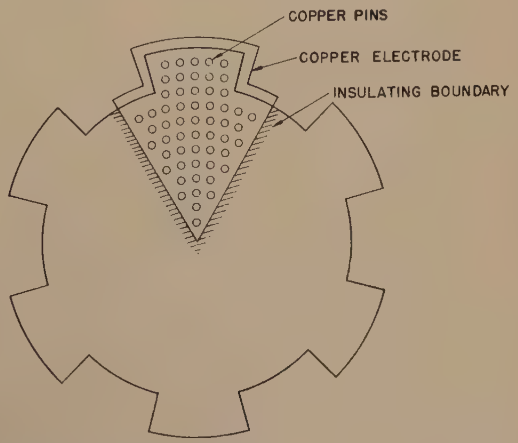


Fig. 5. Technique of simulating the stress distribution of a splined shaft under torsion

THE SERVOMECHANISM

The three probes shown in Fig. 6 pick up the tank potentials where they are located and transmit them to the electronic circuits controlling the motions of the probes. Figs. 1 and 6 show that the probe head can be rotated about its axis and translated in a plane parallel to the upper surface of the electrolyte.

The potentials transmitted to the electronic circuits by the two outer probes control the angular position of the probe head (Fig. 7). The signal from the two outer probes, suitably amplified, drives a d-c motor. The motor rotates a generator selsyn; this in turn rotates the probe head, which is mechanically fastened to the receiver selsyn shaft (Fig. 6). The response of this servo-loop is such that the probe head is rotated until the signal from the two outer probes is in a null condition. This indicates the slope of the equipotential line on which the outer probes are located.

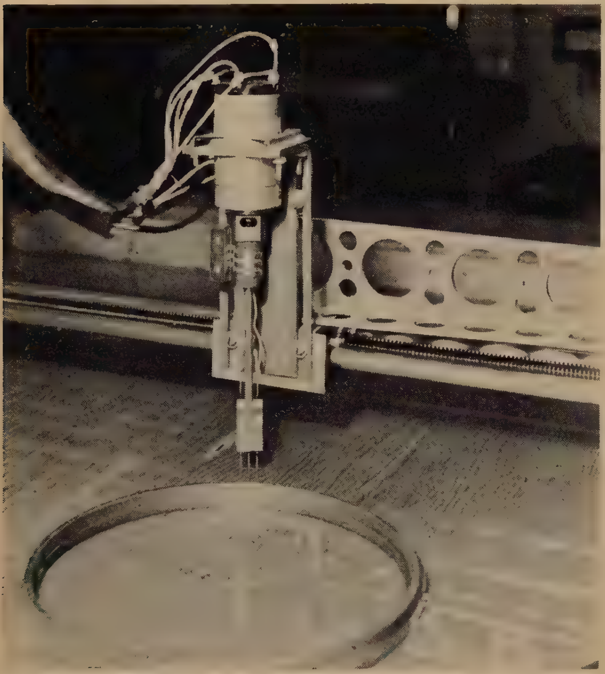


Fig. 6. Close-up of the probe head and the selsyn receiver operating in the electrolytic tank

The angular motor drives not only the generator selsyn but also the resolver and reference selsyn. The two d-c voltages obtained from the resolver vary as the sine and cosine of the angle of rotation. These voltages, suitably amplified, drive the motors that translate the probe head. As a result, the probe is driven in the direction of the slope of the equipotential line as determined by the angular servo-loop.

Since the slope of the equipotential line is determined for a finite increment, in general it only approximates the tangent to the equipotential line. Thus, if the probe head were translated by the action of the drive circuits, the probes would not, in general, closely follow the line. To bring the center probe back in the desired equipotential line, an "error" or "correction" servo-loop is used.

The correction servo-loop also makes it possible for the probes to trace any desired equipotential line. This is accomplished by the use of a precision potentiometer connected across the electrolytic-tank power supply. This potentiometer is calibrated in terms of the percentage of the applied voltage. It can be set for any value between, and including, 0 percent and 100 percent, with a reproducibility and error of less than one part in 1000. The potential determined by the potentiometer setting is compared to the potential of the center probe. The resulting signal, properly amplified, is fed into the correction amplifiers.

The correction amplifiers also have reference voltages fed to them which are derived from the reference selsyn and its associated phase shifter. A 2-kc signal from the oscillator excites the rotor of the reference selsyn, and the output is taken from the stator. The three voltages derived from the stator are in time phase, but their magnitudes are out of phase; that is, their magnitudes vary sinusoidally with the rotation of the rotor, but the interval of rotation between maximum magnitude of one voltage and the next is 120 deg. Mathematically stated, we have

$$E_1 = C \sin \theta \sin \omega t \qquad (14)$$

$$E_2 = C \sin(\theta + 120°) \sin \omega t \qquad (15)$$

$$E_3 = C \sin(\theta + 240°) \sin \omega t \qquad (16)$$

From these three voltages the phase shifter derives two voltages. The magnitudes of these vary respectively as the sine and cosine of the angle of rotation.

The final output of the correction amplifiers is applied to the drive motors through the amplidynes, which also receive excitation from the drive circuits. This results in the correction applied to the probe head being in the direction normal to the equipotential line.

The functions of the three probes may be summarized by stating that the two outside probes control the general direction of motion, while the center probe controls the exact positioning in the tank. The motion of the probe head is transferred by a rigid arm to the drawing board (Fig. 1), where a pen plots the map.

CONSTRUCTION

About 60 sq ft (6 ft by 10 ft) of floor space is required for the tank and drawing boards. The largest tank now used is approximately four feet square. The other tanks used fit inside this large tank.

The lead screws which position the probe are mounted on an angle-iron structure fastened to the tank supports. The electronic control may readily be built into an ordinary relay rack mounting. Twenty amperes at 115 volts, 60 cycles, a-c and eight amperes at 125 volts d-c are required. Future designs will probably operate from a-c or d-c alone, as required.

CONCLUSION

The automatic field-mapping machine is an equipment capable of rapid and accurate mapping of many fields. It does this by automatically locating and

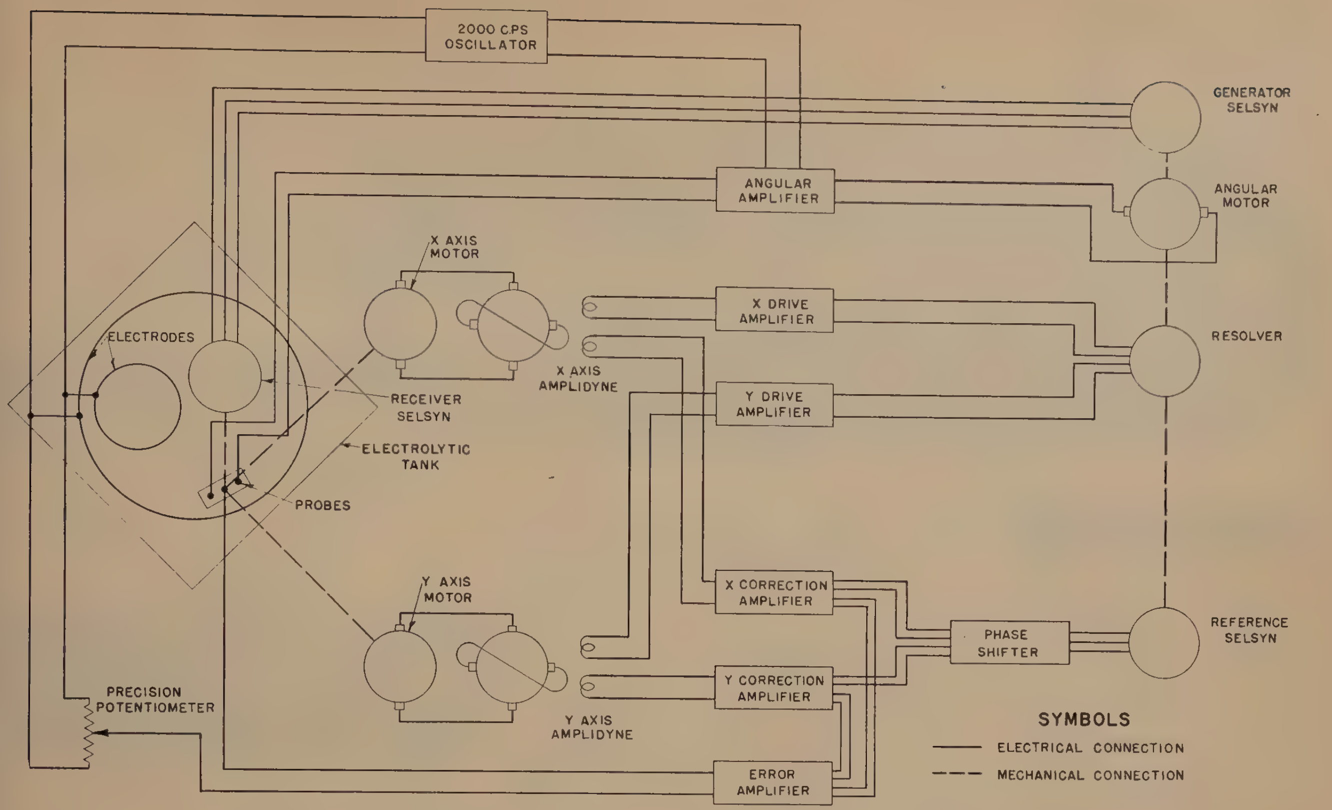
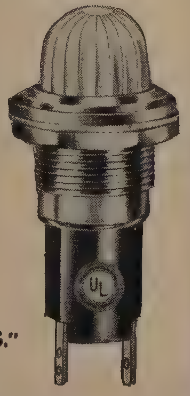


Fig. 7. Simplified block diagram of the automatic field-mapping machine

tracing the equipotential lines of the simulated field. The resulting field maps are the graphical solutions of the field-distribution problems. The speed of field mapping by this machine gives it a great advantage over the common methods of solving complex field distributions by mathematical manipulations or by hand techniques, both of which are lengthy and laborious.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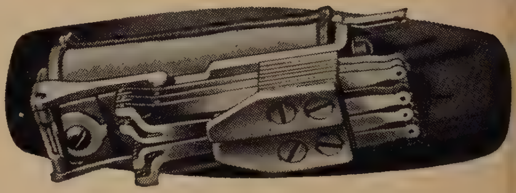

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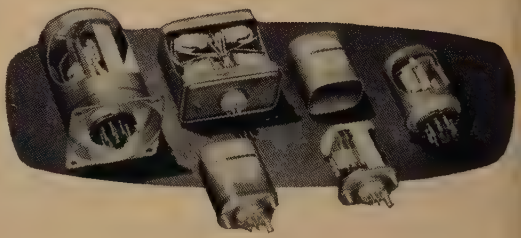

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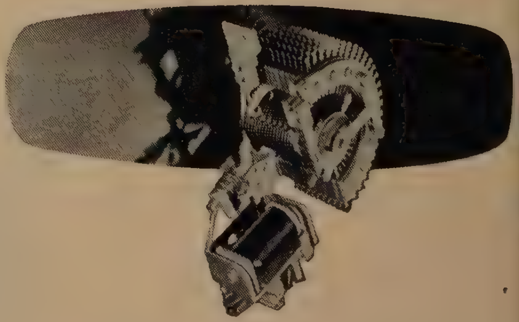

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RELAYS SWITCHES

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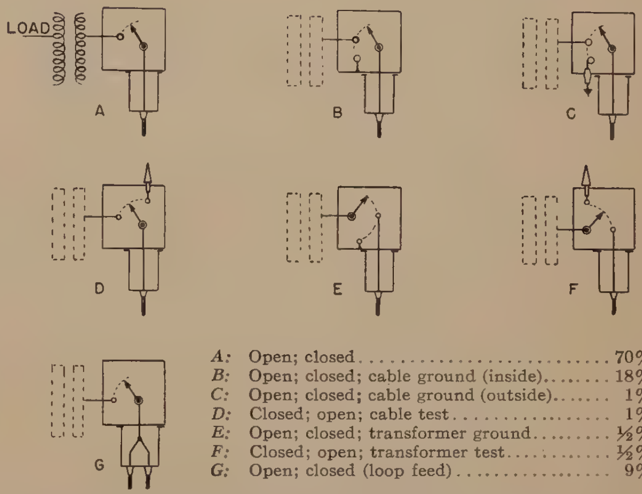
TRANSFORMER DISCONNECTING SWITCHES

Wide demand for different applications has resulted in a varied family of switches in voltage ratings up to 132 kv. The interlock as a safety feature means additional variations in the design of these necessary and useful devices

Palme

By A. PALME
Power Transformer Engineering Division
General Electric Company

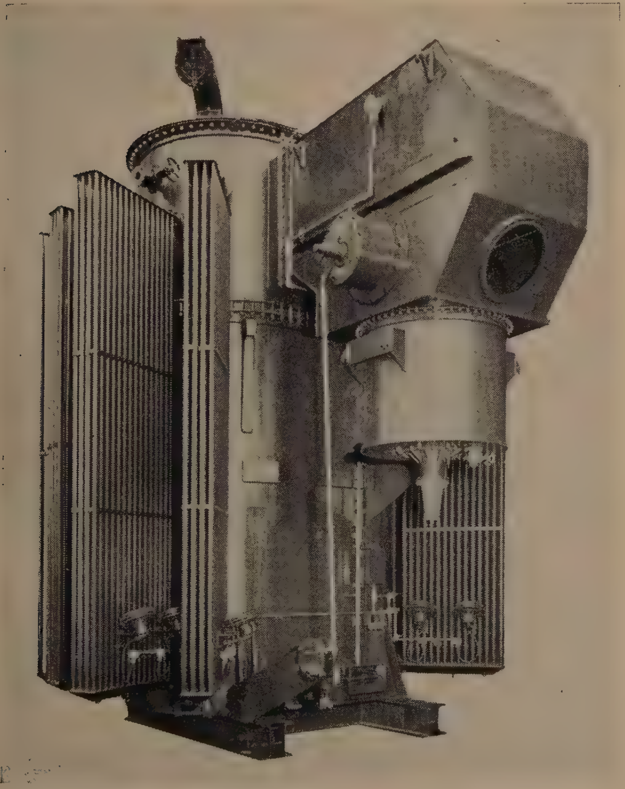


A:	Open; closed	70%
B:	Open; closed; cable ground (inside)	18%
C:	Open; closed; cable ground (outside)	1%
D:	Closed; open; cable test	1%
E:	Open; closed; transformer ground	½%
F:	Closed; open; transformer test	½%
G:	Open; closed (loop feed)	9%

Fig. 1. Schematic diagrams of seven basic switch performances and the relative frequency of their applications during the past ten years

THE disconnecting switch on a transformer can serve many more purposes than its popular name implies. Unlike a circuit breaker, which only connects or disconnects the transformer from its feeding source, the disconnecting switch may in addition ground the feeder or allow high-potential testing of the feeder, two features frequently required and of great value. It may also permit a phasing-out of the cable, and may be arranged to supply a need for grounding or testing the transformer. When more than one transformer is to be fed from the incoming cable, the disconnecting switch on the transformers readily provides the looping point for the incoming and the outgoing cable to the next unit.

Since disconnecting switches can be built for any voltage and current, and have been built for 15 kv to more than 100 kv and up to 2000 amp, it becomes apparent that these many ratings and rating combinations, together with the variety of performances, will result in a great many individual designs of switches. A standardization of these switches would be relatively simple if only the electrical ratings were to be taken care of. It is, however, the variety of performance requirements which complicates matters very considerably. The operating routines of networks and power-distribution systems are so varied and are so well established in each case that the demand for any one of the possible performance features of a disconnect may be well founded.



Oil-immersed transformer disconnecting switch for 132 kv, mounted on a transformer rated 60 cycles, 22,500/30,000 kva, 132/13.2 kv

A standardization of these switches is therefore possible only as far as the general type and the individual parts of the switches are concerned; and even this similarity disappears for circuits of more than 34.5 kv.

The switch can be made in the minimum size when oil is used as the dielectric.

When fireproof construction is required, air-insulated switches are preferred. Switches filled with Pyranol insulating liquid can be used in those applications, but only with certain restrictions as to number of operations, condition of the Pyranol liquid, etc.

FIG. 1 shows schematically seven basic switch performances and the frequency with which these switches have been furnished during the past ten years. It is

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This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR apparent that the simple two-position open-and-closed type of switch has been called for on seven out of every ten orders and therefore represents by far the most popular disconnect type.

All switches with the fulcrum on the cable (*A*, *B*, *C*, *D*, and *G*) are similar in mechanical respects. Likewise all switches with the fulcrum on the transformer (*E* and *F*) are similar.

Most transformer disconnecting switches are essentially of two basic types, determined by the operating voltage. For the three voltage classes of 15, 25, and 34.5 kv, the design has so far been of the rotary type with all three poles mounted on and moved by a central rotating shaft. For higher voltages and three-phase switches, knife switches are used as a rule, with each of the three knives operated individually by an insulating push-pull rod from three bell cranks on a jackshaft. FIG. 2 shows schematically these two switch types. The major insulation between phases and to ground on the rotary types is accomplished with cylindrical midflange porcelains with corrugated surface, babbitted to a common shaft. The knife-type switches have one individual blade per phase, with their fulcrums on post insulators. Current conduction across the bearing is provided by a suitable size of flexible shunt. Each knife blade is moved with a proper length of Herkolite or porcelain tubing.

Disconnecting switches are not designed to rupture load current, but all oil-filled types are capable of breaking the magnetizing current of the transformer to which they are connected. When breaking this flow of magnetizing current, a quick separation between stationary and moving contact is very helpful. Since the operator may not always heed this suggestion, all of these disconnecting switches have quick-break auxiliary fingers on the moving contact, so that no matter how slowly the switch is opened, the final break will be a snap action, brought about by a tension-spring connection between main and auxiliary blades.

Because the magnetizing current of an average power transformer is only two percent or less of the full-load current, the ensuing break duty in oil is very small, resulting in only a minor arc and small gas generation. Disconnecting switches that are provided with about 12 percent air space above the oil level can therefore be completely sealed, without risk of excessive internal pressure due to either heat expansion or gas formation. In fact, the small amount of gas which is caused by the arc is soon absorbed by the oil. Use is made of two methods for guarding against undue internal pressure brought about by any unexpected emergency. For small switches, holding not over 25 gallons of oil, one of the side walls of the switch box is artificially weakened to induce an opening at more than 50 psi. For all larger switches a spring-weighted blow-off valve of large diameter is located on top of the switch box. To prevent a possible spread of the rupturing arc between phases, or from the end phases to ground, insulating barriers are provided on all disconnects.

For types up to 34.5 kv, the entrance of the cable into a disconnect is made with a wipe sleeve or a stuffing box into a compound-filled terminal chamber. Above 34.5 kv, commercial potheads terminate the cable.(1)

The operating mechanism of disconnecting switches is always located remotely from the switch itself. As a rule, the mechanism will be found on the opposite side of the transformer from where the switch is mounted. Thus, when moving the switch blades from one position to another, the operator always has the bulk of the transformer between the switch and himself.

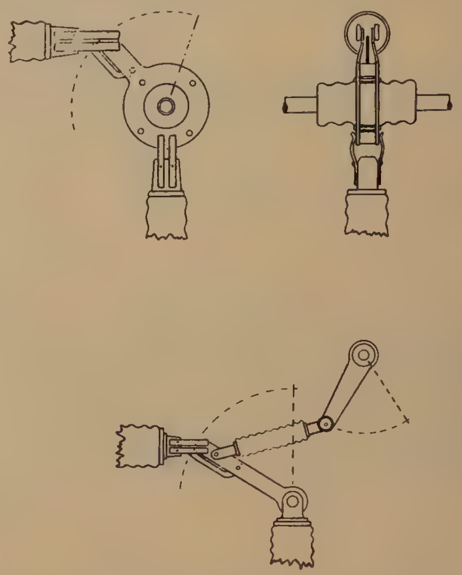

Fig. 2. The rotary type switch (above) is used for 15, 25, and 34.5 kv, the knife type (below) for most higher voltages and three-phase switches

The approved method of opening or closing a disconnect is a determined, positive, and quick completion of the required stroke of the handle. A slow or hesitating motion prolongs arcing, while opening and closing in rapid succession will break and make the inrush current of the transformer, which is many times higher than the sustained magnetizing current and subjects the contacts to severe arcing. To prevent this unnecessary contact wear, the operating mechanism of the disconnects being described contains what might be called a "free-wheeling" feature. That is, once the switch has been closed, it cannot be opened again immediately. To reverse the operation, a bolt in the handle must first be reset; this requires sufficient time to allow the inrush current of the transformer to decay to the steady-state magnetizing current value. The same time delay is encountered when the switch is being opened.

INTERLOCKS

As has been stated earlier, disconnecting switches are not substitutes for circuit breakers, and therefore are not designed to break the load current of the transformer to which they are attached.

In some power systems the disconnect on a transformer is padlocked and is not permitted to be operated except by a fully authorized person, who can be relied upon to make sure that the transformer is not carrying load before the switch is opened. In fact, the only key to the padlock may be in that person's possession. In most systems, however, a less restricted yet fully safe method has to be provided to guard against incorrect operation of disconnects. Interlocks are then in order, of which two types are widely used: the mechanical key type and the electric type.

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(1)"Cable Termination for Transformers and Transformer Disconnecting Switches," A. Palme, GENERAL ELECTRIC REVIEW, vol. 51, Dec. 1948, p. 36.

By far the simplest, least expensive, and perfectly foolproof method is the use of transferable keys, among which the Kirk and Cory constructions are outstanding examples. These are plunger-type locks, so arranged that the key can be removed from the lock only when the bolt is either extended (locking) or retracted (unlocking). A simple example will explain this.

An operator wishing to open the disconnect of a loaded transformer arrives at the operating mechanism of the switch to find its handle locked and immovable, the key to the lock missing. He knows that the missing key can be found at the load circuit breaker, but his attempt to remove the key is futile. He will therefore trip that breaker, thus dropping the load on the transformer, and will lock the breaker open with its key. Now that key will be removable, and he can take it out to unlock with it the lock on the disconnect, which can now be opened safely. No false move is possible in this simple routine.

For disconnecting switches with a cable-ground position, two key locks with two different key patterns are provided. One key, co-ordinated with the load breaker, guards against opening the load by the disconnect and permits the movement of the disconnect only between the open and closed positions, locking against the ground position. The other key, co-ordinated with the primary breaker or a horn-gap switch, makes it possible to unlock the switch handle towards the ground position, because that key is available only *after* the primary breaker or horn-gap switch has been opened and locked open.

It is of interest to mention that the manufacturers of these locks keep an accurate and complete record of locks furnished for all applications, and will not duplicate key patterns in the same geographic location. Therefore, when filling an order for interlocks, the vendors always require information about the actual location of the interlocked system.

The other type of widely used interlocks is the electrical—or, more accurately stated, electromagnetic—lock. The locking is accomplished by a plunger actuated by a solenoid which may be energized by 24 or 125 volts direct current or 115 or 230 volts alternating current of 60, 50, or 25 cycles. Depending upon whether the physical location of the lock solenoid is above or below the locking disk with its notches for the locking plunger, the actual *locking* will be accomplished by either gravity or current in the solenoid; the *unlocking* will then be done by current or gravity respectively. Because of this very important difference, it is necessary to distinguish between fail-safe and fail-unsafe electric interlocks.

If an electric lock has to depend on current to do its locking, it is conceivable that the current may fail, that a wire in the circuit may have broken, that some contacts are not "made," or that the solenoid has failed. In any of these cases the lock will open, because the plunger drops out of the locking notch and frees the switch. With properly designed solenoids and reliably made wiring, none of those faults is likely to develop, but the possibility of any one of them cannot be entirely dismissed; under such circumstances, there may be a sense of false security. Nevertheless, this type of electric lock is often used, and the current of the transformer itself is depended upon to do the locking.

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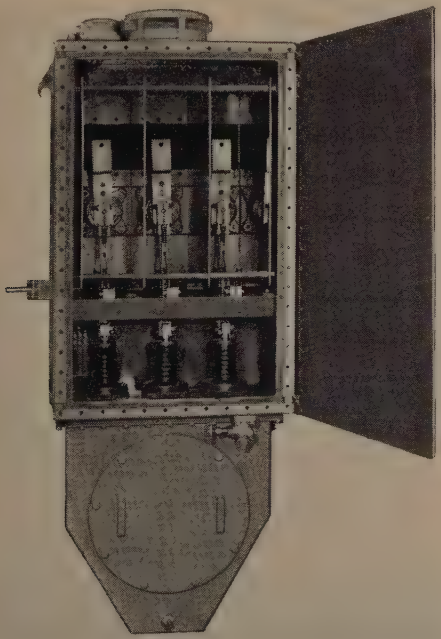
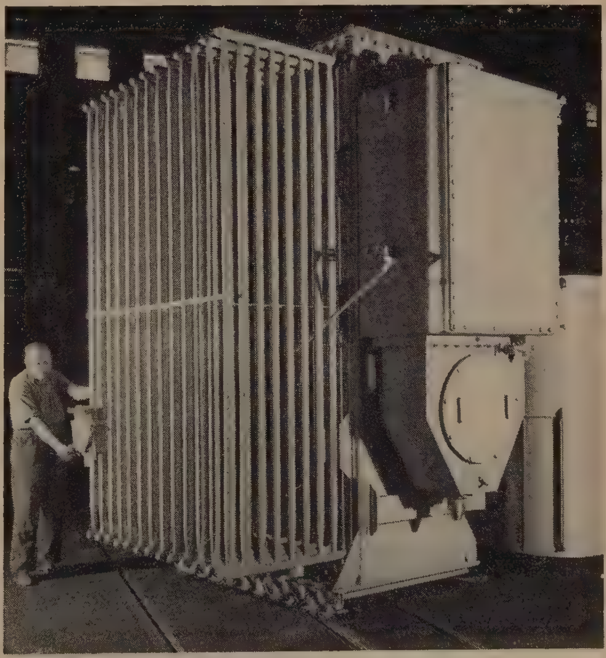
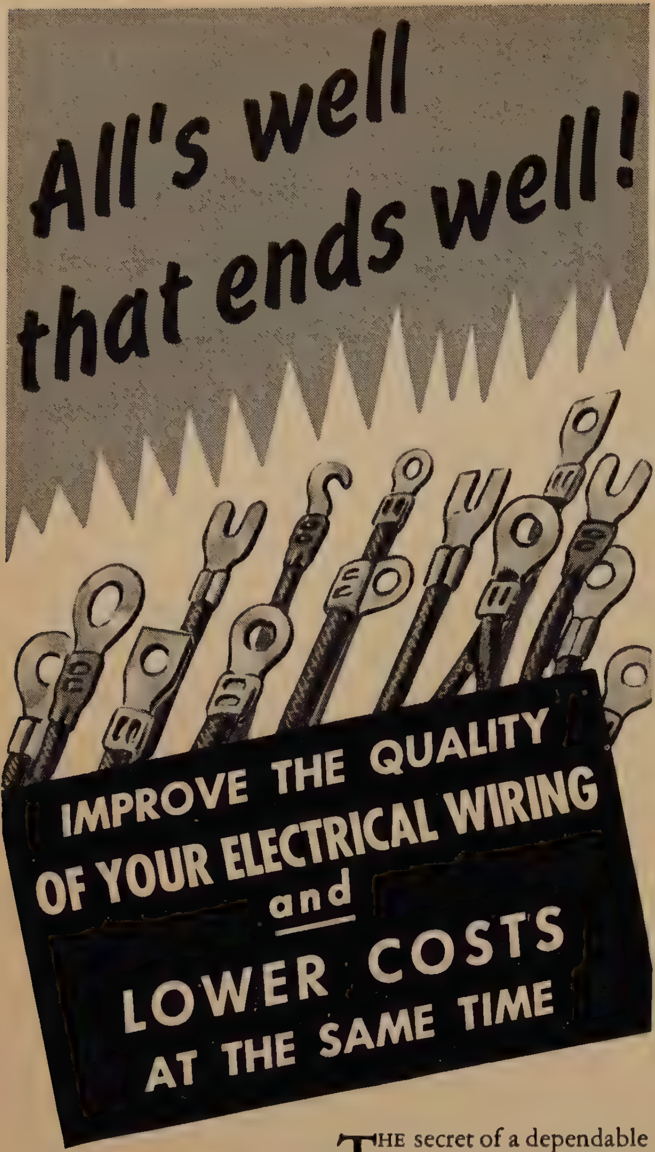


Transformer disconnecting switch rated 34.5 kv, 400 amp. The terminal chamber is below the switchbox. (See also illustration at right)



The switch as mounted on a 3125-kva power transformer. Note remoteness of operating position from switch enclosure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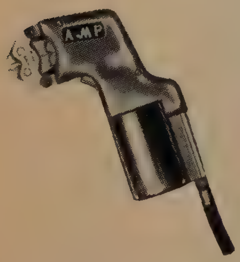

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TRANSFORMER DISCONNECTING SWITCHES

(Continued from preceding page)

On the other hand, the solenoid can be located *above* the locking disk of the switch, so that gravity, which never fails, does the locking, and some independent current supply can, when required, do the unlocking. It is obvious that the switch will remain locked by gravity, regardless of other malfunctions in the system, until it is intentionally unlocked by an independent power source. The independent power supply is usually a small station battery of 48 to 125 volts d.c.

CONCLUSION

The original conception of the purpose of a transformer disconnecting switch—merely to connect or to disconnect an unloaded transformer to or from its feeding source—would have made such a device ideal for economic standardization. However, as the trade has become more and more familiar with these switches, the demand upon the actual performance of the device has grown until there is finally a whole family of them in voltage classes up to 132 kilovolts, with a great variety of performances.

The interlocks, often specially designed to fit and to make safe a specific installation, are another item that has made the application of disconnects more involved.

Thus grew the simple "on" and "off" switch to a fairly complex addition to modern power transformers.

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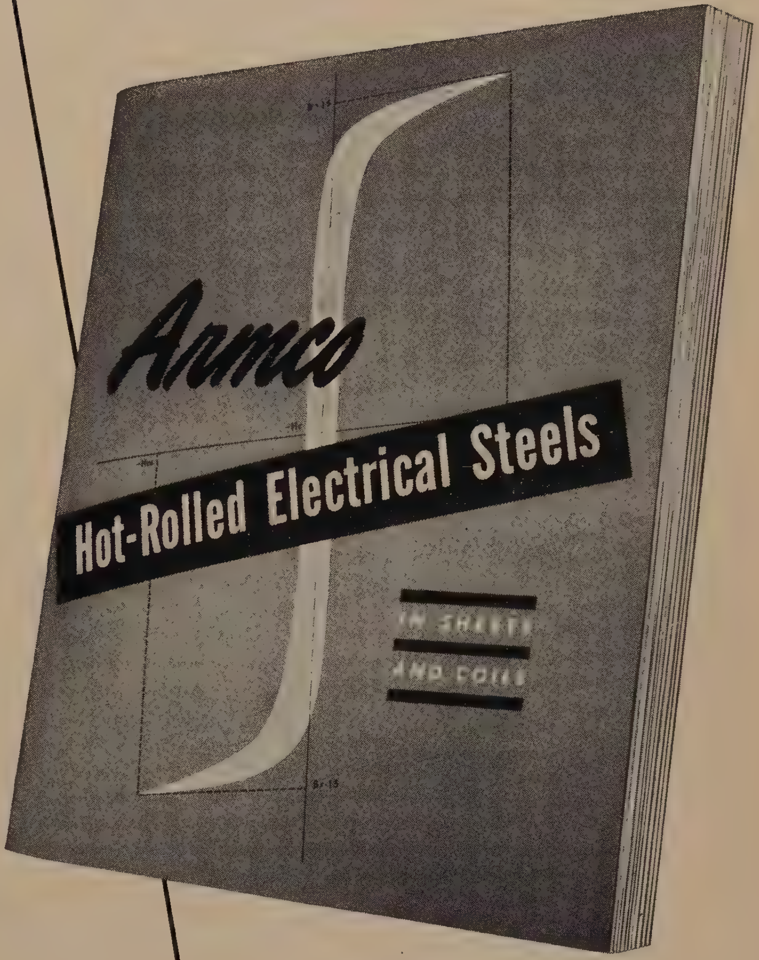

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PROTECTIVE ATMOSPHERES IN INDUSTRY . . Part XI

Thorough understanding of elementary principles and basic methods for safe handling of atmosphere gases is of primary importance in furnace operation. Means of purging and suggested safe procedures. Typical safety devices

By A. G. HOTCHKISS and H. M. WEBBER
Industrial Heating Divisions, General Electric Company

THE proper handling of gas is of primary importance for reasons of safety. It is important also with respect to equipment operation in accomplishing the maximum results from the use of the gas as protective atmospheres. The handling of gas, like the handling of electricity, can be accomplished safely and easily when certain basic methods and principles are understood and employed. Although all specific problems encountered in the handling of gases can not be covered in detail, the general principles involved in the safe handling of protective atmospheres will be presented in this part.

METHODS FOR SAFE HANDLING OF ATMOSPHERE GASES

Even though thousands of atmosphere-gas producers and protective-atmosphere furnaces are in safe and reliable operation every day, some elementary principles in the safe handling of gases are still not thoroughly understood by all operators. In operating all such equipments there are two potential hazards which should be borne in mind: first, the possible danger of asphyxiation of personnel, either by dilution of the oxygen in the air or by the presence of toxic gases, such as carbon monoxide; and second, the potential explosion hazard which relates to all those atmospheres which contain combustible gases in amounts sufficient to burn, with the possibility of damage to both personnel and equipment. Both of these possible hazards are completely eliminated by properly installed and operated equipment.

The possibility of asphyxiation can be present at all times in the immediate vicinity of any protective atmosphere furnace or gas generator. Thus, it becomes important that leakage of gases from the generating equipment and the conducting pipe line be reduced to a minimum. The leakage of atmosphere from furnaces is normally controlled by adequate room ventilation, exhaust systems, or by combustion of the escaping gases. It is important also to guard against a repair crew's cutting into lines which contain atmosphere gases; and to thoroughly remove such gases from confined furnace chambers when it becomes necessary for personnel to enter them, and in addition to provide a continuous flow of fresh air during repair operations.

When an atmosphere being used in a furnace contains carbon monoxide—and a majority of furnace atmospheres are in this category—all personnel in the immediate vicinity should be warned of the toxic effect of unburned gases containing carbon monoxide. The assurance of nontoxic conditions in the area can be proved by the use of any one of several carbon-monoxide detectors which are available for measuring concentrations as low as a few parts per million.(26)

To obtain best results with maximum safety when operating a protective-atmosphere furnace, the operating personnel should be thoroughly trained and completely competent in the handling of gases. Moreover, to insure a satisfactory product and maintain safe operating conditions, periodic testing of the generated gas, furnace atmosphere, and the operation of installed safety devices is recommended. Maintaining all equipment in best operating condition is a very important factor, and also reduces the possibility of unexpected shutdowns.

In the handling of gases, the potential explosion hazard is reduced practically to zero if the operator understands (or is thoroughly familiar with):

(1). The difference between inert (nonflammable) and flammable gases

(2). The possible variety of effects in purging, resulting from the difference in density of various gases

(3). That flammable gases may be introduced safely into any chamber whose temperature is above the ignition point (1400 F or higher)

(4). That the introduction of a flammable gas into any chamber containing air whose temperature is below the ignition point (1400 F or below) may create a hazardous condition

(5). The approved methods and rules for purging various types of chambers.

PRINCIPLES OF PURGING

Purging is the process of replacing one gas in a chamber or container with another gas. With reference

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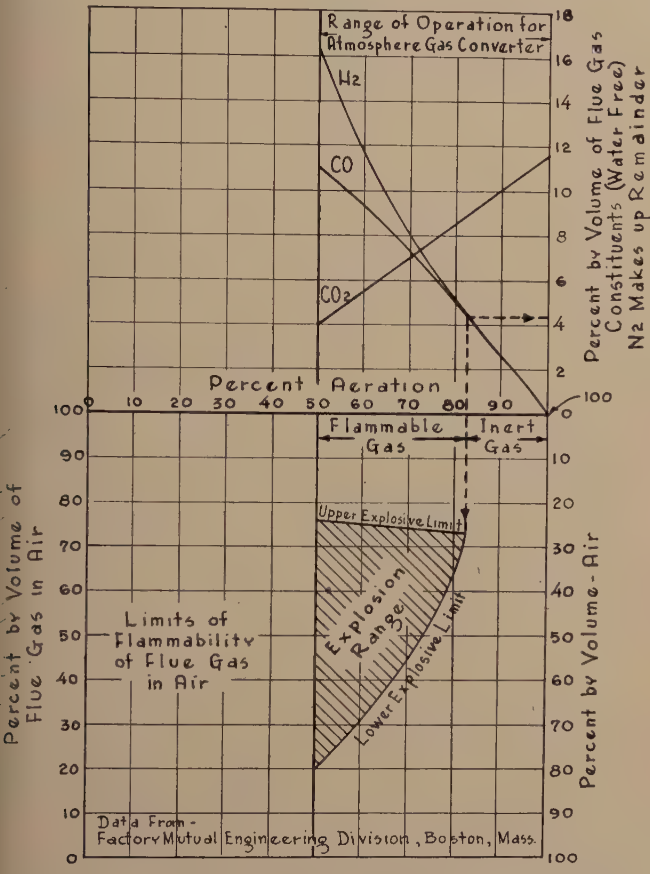
*The following will facilitate the location of material published in earlier parts of this serial:

Part	*Issue*	*Figs.*	*Equations*	*Tables*	*Footnotes*
Part I	Nov. 1948, p. 29	1 to 6	None	I and II	None
Part II	Dec. 1948, p. 41	7 to 14	(1) to (18)	III and IV	(1) to (9)
Part III	Feb. 1949, p. 37	15 to 23	None	V and VI	None
Part IV	Mar. 1949, p. 25	24 to 35	None	VII	None
Part V	Apr. 1949, p. 25	36 to 41	None	VIII to X	(10) and (11)
Part VI	May 1949, p. 30	42 to 54	None	XI to XII	(12)
Part VII	June 1949, p. 33	55 to 70	None	XIII to XV	(13) to (17)
Part VIII	July 1949, p. 32	71 to 89	None	XVI	(18) to (23)
Part IX	Aug. 1949, p. 26	90 to 97	None	None	None
Part X	Sept. 1949, p. 38	98 to 108	None	XVII to XIX	(24) and (25)

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR to furnaces this usually means replacing the air with a furnace atmosphere or replacing the furnace atmosphere with air.

Flammable and Inert Mixtures

To understand the reasons for certain methods of purging, it will be necessary to know the difference between an inert gas (a gas which will not burn) and a flammable gas (a gas which will burn).(27) Reference to Table XVII shows the lowest and highest percentages of various gases which, when mixed with air and ignited, will burn readily. The wider the spread of these limits, the greater the danger range. In this respect, then, hydrogen is the most difficult to handle and propane the least.



Data From - Factory Mutual Engineering Division, Boston, Mass.

Fig. 109. Analysis of gas from an atmosphere-gas converter and the explosion range (shaded) when mixed with air

From the standpoint of purging, a flammable mixture will exist at any time the percentage of the gas or gases in an air mixture rises above the lower limits; for example, four percent or more of hydrogen in air is considered flammable.

Generally speaking, an inert gas is considered to be any one of the gases which do not burn, such as nitrogen and carbon dioxide. From the standpoint of furnace atmospheres, however, it can be considered that any gas or mixture of gases is inert if the amount of combustible gases included is below the lower limit of flammability. Thus, a gas-air mixture containing less than four percent hydrogen is considered inert.

Atmospheres produced from combusted fuel gas with exothermic-type reaction, such as E1 and E2 in Table I, can generally be adjusted by means of the air-gas ratio to produce an inert gas. Fig. 109 presents information which readily permits selecting an atmosphere of this type that would be considered inert.

The top part of this chart shows the average analyses of the products of combustion from an atmosphere gas converter over the normal range of adjustment. It will be noticed that these curves are very similar to those shown in Fig. 28.

However, instead of being plotted according to an air-gas ratio, which is variable for different fuel gases, these curves are plotted according to percent aeration. The volume ratio of the air divided by the fuel in an unburned mixture where the minimum air for chemically complete oxidation is present is defined as 100-percent aeration. For example, the 100-percent aeration mixture for 530 Btu manufactured gas is about 4.6 cu ft of air divided by 1.0 cu ft of gas which gives a ratio of 4.6 to 1. Fifty-percent aeration then would be 2.3 cu ft of air to 1 cu ft of gas, or a ratio of 2.3 to 1.

Since percent aeration is used instead of actual air-gas ratios, this chart applies approximately to natural gas, propane, and butane, as well as manufactured gas.

The lower portion of Fig. 109, the crosshatched zone, indicates the explosive range of mixtures of the products of combustion or flue gas, with air. The dotted line, then, indicates the division point between a flammable and an inert gas. Any mixture which will produce a gas analysis falling on this line or to the right of it is considered inert. A setting which will produce a gas that falls to the left of this line is considered flammable, and any mixture with air that falls within the crosshatched zone is explosive.

Density Considerations

When a chamber is purged by replacing one gas with another, the least amount of mixing generally is desirable and permits the most rapid purging.

If the density of the two gases is approximately the same, as, for example, air and nitrogen, it will make little difference as to the manner in which the two gases are brought together. For instance, if the air in a vertical container is to be displaced by nitrogen, the nitrogen could be introduced at the top or at the bottom, whichever is more convenient, assuming an opening is at the opposite end or side for the escaping gas.

If, however, it is desired to remove the nitrogen from a vertical container and replace it with hydrogen, the density of the two gases should be considered (Table XVII). For instance, if hydrogen (density of 0.07) is introduced at the bottom of the cylinder, with an opening at the top to release the nitrogen (density of 0.97), the very light hydrogen will have a tendency to rise immediately to the top of the container and will thus mix with the nitrogen and escape along with it. If, however, the flow is reversed and the hydrogen introduced at the top with an opening provided near the bottom for the nitrogen to escape, the hydrogen, because of its low density, will tend to collect in the top of the cylinder, while the nitrogen, with a high density, will readily flow from the bottom of the cylinder. Thus, the nitrogen will be removed with a minimum flow of hydrogen and with minimum mixing of the two gases.

It follows that if such a cylinder contains hydrogen, and it is desired to replace this hydrogen with nitrogen, the heavier nitrogen should be introduced at the bottom while the light hydrogen is permitted to escape from the top opening.

The matter of density, then, is most important when handling gases containing large amounts of hydrogen and when the chambers to be purged extend in a vertical position rather than horizontal.

Ignition Temperatures

Combustion data(28) shown in Table XVII indicate that the upper ignition temperatures* of hydrogen and carbon monoxide, the two flammable gases most generally encountered in furnace atmospheres, are about 1094 and 1216 F respectively. The range of methane, which is sometimes encountered in very small quantities, is 1200 to 1382 F. In general, a temperature of 1400 F is considered the minimum temperature that will immediately ignite a flammable mixture of these gases in air or oxygen. It can therefore be readily understood that any flammable gas can be introduced into a chamber containing air which is 1400 F or above with complete safety, since the flammable gas will immediately ignite and burn with the air as soon as the gas enters the chamber. This burning will continue until the oxygen is almost entirely consumed. Conversely, air can be introduced into any chamber which contains a flammable gas and which is 1400 F or above with perfect safety, since ignition will immediately take place and all flammable gas will be consumed if the flow of air is continued.

From the preceding paragraph, it should now be readily understood how a hazardous condition can exist in an attempt to introduce a flammable gas into a chamber containing air when all points of this chamber are below the ignition temperature of 1400 F. Under such conditions, the flammable gas and the air may mix together and, as previously pointed out, form combustible mixtures at certain stages of the mixing process. Any flame or spark brought near the exhaust where this mixture is leaving the chamber will cause ignition, which not only burns the escaping mixture but might cause the entire volume of mixture contained in the chamber to burn at once, thereby causing an explosion. Any chamber with temperature below the ignition point (1400 F) should therefore be considered hazardous when flammable gases are being handled, and certain approved methods of purging such containers must be rigidly followed.

METHODS OF PURGING

One of the fundamental rules for safe handling of gases is to avoid mixtures of flammable gases with air. It follows then that for flammable gases, it is desirable that the air be removed by an inert gas before the flammable gas is introduced. Unfortunately, the design of atmosphere generators and the design of some furnaces does not always permit this method to be economically used. Therefore, other so-called safe procedures have been established.

Critical Periods

In the operation of purging a protective atmosphere there are three possible critical periods in the handling of flammable gases:

(1). When introducing the atmosphere gas into the furnace chamber to remove the air

(2). When removing the atmosphere gas and allowing air to re-enter the furnace

(3). When the flow of atmosphere gas is accidentally interrupted during normal operation.

To determine the status of an atmosphere in a furnace chamber during the purging process, the operator usually depends on gas-volume measurements and time of flow. It has been determined experimentally that to completely purge the air from a chamber and reduce the oxygen content to about zero, will on the average require a volume of atmosphere gas equal to five volume changes of the chamber being purged. This is a conservative figure to use since four volume changes will ordinarily reduce the oxygen content to three percent or less, which is considered a safe condition.

Sometimes it is necessary or desirable, however, to analyze the gas composition in the furnace chamber to make certain of the conditions. When purging out air, oxygen can be measured by an Orsat analyzer or an automatic oxygen analyzer as explained in Part VIII. Also described in Part VIII is the Ranarex specific-gravity indicator which is used in many instances to measure the degree of purging,(20) since most flammable atmospheres have a specific gravity considerably below that of air.

Where the purging involves the removal of a flammable gas by an inert gas, a combustibles analyzer or hydrogen analyzer (Part VIII) can be used to indicate when purging is sufficiently complete to be safe.

As a substitute for purging with inert gases, the burn-out method of introducing or removing a flammable gas from a furnace chamber is used. In the starting up of a furnace, the definitely flammable gas is ignited at the point where it enters the furnace chamber, and (as the name indicates) by combustion reduces the oxygen content. When shutting down, igniting the flammable gas at a door, and then opening the door wide, will permit sufficient air for the burning out of all the flammable gas within the chamber. In either instance, during the interval of burnout, continued ignition of the mixture as it is formed prevents a dangerous accumulation.

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*Published data vary, depending on authorities and methods of testing.

The accidental interruption of the flow of atmosphere gas during normal operation can generally be caused by either electric power failure or loss of the fuel gas. Whichever the cause, the operator should be warned immediately; some methods of accomplishing this will be considered under safety devices. If, in such emergency conditions, the furnace is filled with a flammable atmosphere, the seriousness of the hazard will depend on the speed with which the operator burns out the heating and cooling chambers. He should *immediately* admit room air to hot sections to replace flammable atmosphere before the temperature drops below 1400 F. Pilots, gas curtains, or other ignition means should be placed at the outside doors of sections below 1400 F; then the doors may be opened wide. The ignition flames should be kept burning until these sections are completely burned out.

SUGGESTED SAFE PROCEDURES FOR VARIOUS TYPES OF FURNACES

Closed Chambers with Openings at the Bottom

This type of furnace includes the bell type, elevator type, and tower type. It is desirable to purge with inert gas, but where inert gas cannot be used, the following procedure is recommended.

Bell-type Furnace. For this example it is assumed that work is placed under a tight retort which is sealed to the load-supporting base by sand or liquid seals, and the furnace containing the heating units is placed over this closed retort. It is assumed that the atmosphere used is a flammable gas and that the purging of the air with the gas is done with the retort cold.

(1). To introduce the flammable gas:

(a). Place a pilot flame near the gas inlet or inlets on the base, and start the flow of gas. Be sure that the gas is burning freely at all inlets
(b). Lower the retort over the load and into the seal. The flame will burn out the entrapped air and prevent an unsafe mixture from forming
(c). Circulating fans should not be started until about 10 min after the retort is sealed.

(2). To remove the flammable gas (retort cold):

(a). Turn off circulating fan and allow it time to stop
(b). Turn off the atmosphere gas
(c). Immediately raise the retort slowly, and when it is 2 or 3 ft above the base, ignite the gas under the retort, using a torch with a long handle. The air will enter and burn out the gas.

Elevator-type furnaces. This type of furnace is similar to the bell-type except that the furnace is supported off the floor in a permanent position and the load is raised up into the furnace on a supporting base which closes and seals the bottom opening of the furnace. It is assumed that the work is loaded on the base, with no retort covering it, and the flammable atmosphere is in contact with the work and with the furnace chamber. The atmosphere inlets are generally through the roof of the furnace.

(1). To introduce the gas:

(a). If the furnace is above the ignition point (1400 F), the flammable gas should be turned on while the bottom of the furnace is open. The incoming atmosphere gas will immediately ignite as it enters the chamber
(b). If the furnace is cold, the flammable gas should be turned on and immediately ignited by a long torch while the bottom of the furnace is open. Make sure the incoming gas continues to burn
(c). The base should be raised until it seals with the bottom flange of the furnace
(d). The pilot lights should be turned on at exhaust vents just above the base seal. When the flammable gas burns at these exhausts, the furnace is considered to be purged.

(2). To remove the gas:

(a). Increase the flow of atmosphere gas if sufficient quantity is available to establish a slight pressure within the furnace. Place pilot lights at a point near the seal of the base at the bottom of the furnace
(b). Lower the furnace base until the seal is broken; the escaping gas will immediately ignite
(c). After the base has been removed, turn off the atmosphere gas, and the chamber will burn out.

Tower-type continuous furnace. This type of furnace may have an attached cooling chamber. Both heating and cooling chambers would be closed at the bottom except for small entrance and exit openings.

(1). Whether the heating chamber is cold or hot when the air is purged out, it is strongly recommended that an inert gas be used to remove the air before introducing the flammable gas. The burn-out method is not recommended.

(2). To remove the flammable gas, an inert gas should be used to reduce the hydrogen content to 4 percent or less before air is allowed to enter. Because of the almost totally closed chamber, the burn-out method cannot be relied upon to proceed to completion. For effective purging, consider the relative specific gravity of the atmosphere gas and purging gas, as explained under Density Considerations.

When using flammable gases in this type of furnace, it is essential that a standby source of inert gas always be available in such quantity as to purge the furnace to a safe point in an emergency.

Batch-type and Horizontal Continuous Furnaces, with and without Cooling Chambers Attached. These recommendations are based on a report entitled "Safe Operating Procedures for Different Types of Special Atmosphere Furnaces," compiled by Mr. J. B. Smith of the Associated Factory Mutual Fire Insurance Company.(29)

For convenience, this section is divided into three classes according to different operating temperatures.

Furnaces with all sections above 1400 F (no cooling chamber) as indicated by the temperature controllers. Either the method of purging with inert gas or the method of burning out is acceptable from the explosion hazard standpoint. With the burning-out procedure, all sections should be maintained over 1400 F during the beginning or stopping of the flow of flammable atmosphere. Under these conditions, mixtures of flammable atmosphere and air continue to be burned as they are formed until flame appears at the slightly open entrance and exit doors when starting up; and on shutting down, until all flame disappears from inside the furnace after opening the doors and shutting off the flow of flammable atmosphere. By these indications, the changeover from one atmosphere to another is known to be complete.

Furnaces consisting of heating chambers and attached cooling chambers where the heating chambers are 1400 F or over and the cooling chambers are under 1400 F. Where inert gas cannot be used for purging, these recommendations are given:

(1). To introduce the gas (starting up):

(a). The flammable atmosphere should be introduced into the heating chamber alone, and only after the chamber has reached the temperature of 1400 F and with the chamber entrance door closed. The door between heating and cooling chambers should be wide open, and the cooling chamber exit door opened 2 or 3 in.

(b). The flow of flammable atmosphere should be continued, filling the heating chamber, then the cooling chamber. When flame appears at the heating-chamber and cooling-chamber entrance and exit doors, it is an indication that all air has been burned out

(c). At this time, pilots and/or flame curtains can be lighted at cooling-chamber and heating-chamber doors. Now the furnace is ready for production.

(2). To remove the gas (shutting down):

(a). Maintain the heating chamber at 1400 F or above

(b). Open wide the door between heating and cooling chambers

(c). Apply a continuous reliable ignition source such as a pilot, flame curtain, or portable torch with a flame extending slightly above the hearth level (a flame which is too high tends to exclude fresh air) at both heating-chamber entrance and cooling-chamber exit doors

(d). Open wide the heating-chamber and cooling-chamber exit and entrance doors

(e). Shut off the flow of flammable atmosphere to all inlets of the heating and cooling chambers. The gas will burn from each end backward throughout the heating chamber and cooling chamber in a very few minutes. (Caution: Be certain that shut-off valves close tightly and do not leak Cock-type valves are preferred.)

(f). With both chambers now being filled with air, pilots and/or flame curtains may be extinguished and the heating units shut off.

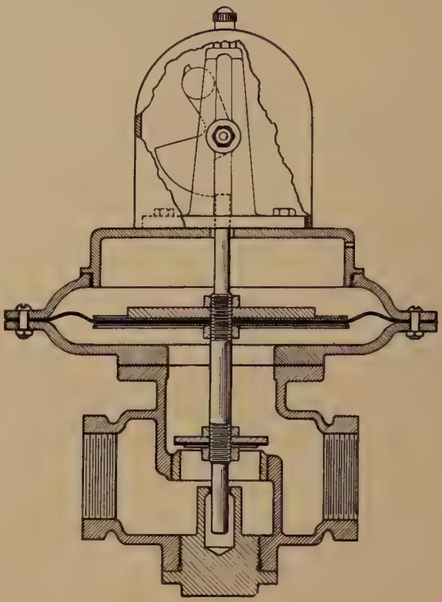

Fig. 110. Safety shut-off gas valve. Closes when pressure is low; must be manually opened (*Courtesy Eclipse Fuel Engineering Company, Rockford, Illinois.*)

A furnace with no section above 1400 F: In the absence of a reliable ignition temperature, the advantage, from the safety standpoint, of purging with inert gas is most pronounced. If inert gas is not available, the burn-out method can be used in this manner:

(1). Introducing the gas (starting up):

(a). After the furnace is at operating temperature with heating units "on", a portable lighting torch should be placed at the point or points inside the furnace where the flammable atmosphere is to be admitted

(b). Start the flow of flammable atmosphere

(c). After the incoming atmosphere is ignited at the inlet ports, remove the torch

(d). Doors should be moved to the closed position and the flow of flammable atmosphere gas continued, except for continuous furnaces, where door positions will be the same as in 1 (a) under procedure for furnaces with heating chambers at 1400 F or over

(e). The flow of flammable atmosphere should be continued until the flame appears at the heating-chamber and cooling-chamber entrance and exit doors

(f). At this time apply continuous reliable ignition sources, such as permanent pilots and/or flame curtains, at the entrance and exit doors. The furnace is now safe to put into operation, and proper atmosphere will be maintained as long as the gas flow is continued. Pilots and/or flame curtains should be maintained to insure ignition of the escaping gas as soon as doors are opened.

(2). To remove the gas (shutting down):

(a). Maintain the heating units "on"

(b). Subsequent steps are identical to procedure given in 2 (b) to 2 (f) inclusive in the preceding section.

If the foregoing procedures are followed, safe operation of protective atmosphere furnaces is assured.

SAFETY DEVICES

The majority of furnace atmospheres in use today are generated by the combustion or reformation of mixtures of gas and air. Certain safety devices have been found necessary or highly desirable to insure safe operation of the gas-producing equipment and the furnaces with which it is used.

To meet the required safety standards, the atmosphere generating equipment should be designed to these specifications:

(1). It should be reliable and designed for continuous 24-hr operation for months at a time without a shutdown. This requires properly selected heavy-duty motor and compressor units. Some automatic means of maintaining the set ratio of air-to-gas (Part IX) over the normal range of volume fluctuation of the equipment is also essential

(2). Indicating flow meters (Part IX) for both gas and air will permit a quick check on the air-gas ratio and output volume of the producer

(3). When the source of fuel gas fails, automatic means should be provided to close a valve in the fuel-gas line and stop the compressor, and to notify the operator by means of an audible signal

(4). In the event of loss of power which would stop the blower or mixture compressor, the fuel-gas line should be closed with a solenoid valve of the manually opened type except for very small sizes. A warning signal also would be desirable

(5). While getting the generator started and prior to the establishment of a stable operating condition, positive arrangements should be made to vent the output of the generator to atmosphere and prevent the gas from entering the furnace.

Fuel Shut-off Valves

If the flow of fuel gas to the generating equipment should be shut off, it would then be possible to pump air through the generator and into the furnace. Fire insurance underwriters recommend two methods of handling this problem. One device, Fig. 110, is a weight-locked-type diaphragm valve placed in the fuel-gas line. In normal operation, the pressure of the gas on the bottom side of the diaphragm holds the valve open. If the gas pressure on the line drops to an unsafe minimum, the valve will close allowing the weighted lock to move into position over the stem, locking it closed. After gas pressure is restored, the valve must be opened by the operator. An electric switch can be operated in conjunction with the valve lock to furnish an interlocking circuit with the compressor, or to operate a signal.

Another device is the solenoid trip valve, Fig. 111. This valve is manually opened and is held in the open position by a solenoid energized through the electrical circuit which supplies the compressing equipment. Upon power failure, the valve is closed by spring pressure or by weight. A pressure switch, Fig. 112, actuated by the pressure on the fuel-gas line, could be connected into the electrical circuit and operate in such a manner as to open the circuit to the solenoid if there is loss of pressure on the fuel-gas line. This arrangement gives double protection against the loss of electric power and gas pressure. When the power

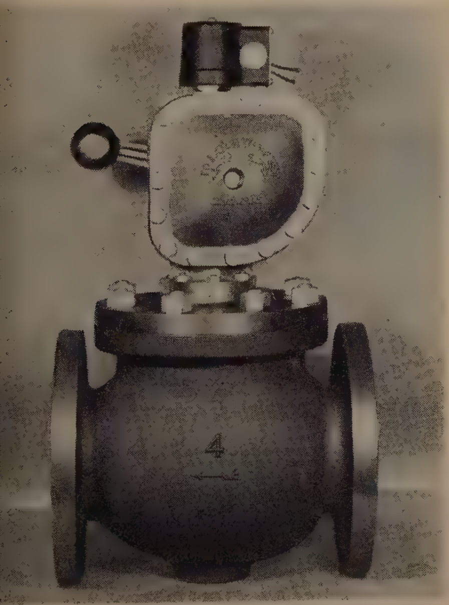

Fig. 111. Solenoid trip safety shut-off valve. Closes when electric power fails; must be manually opened (*Courtesy Automatic Switch Corporation, Orange, N. J.*)

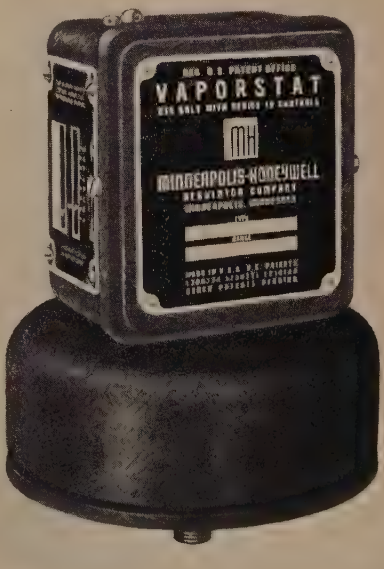

Fig. 112. Pressure-operated electric switch that can be adjusted to open or close the circuit when gas pressure is reduced below a safe minimum (*Courtesy Minneapolis-Honeywell Regulator Company, Minneapolis, Minn.*)

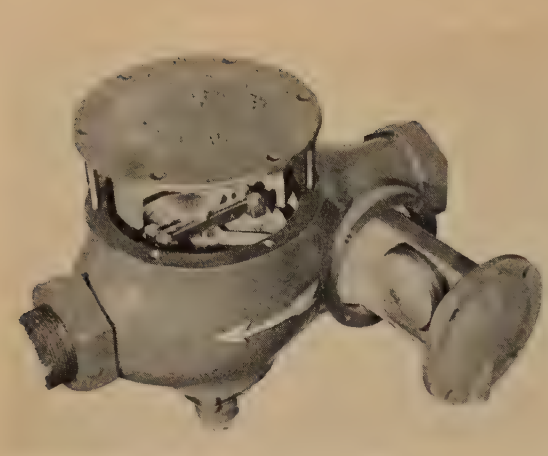

Fig. 113 (a). Automatic fire check partially disassembled to show the flame arresting screen, bimetallic strips holding open the shut-off valve, and the check valve

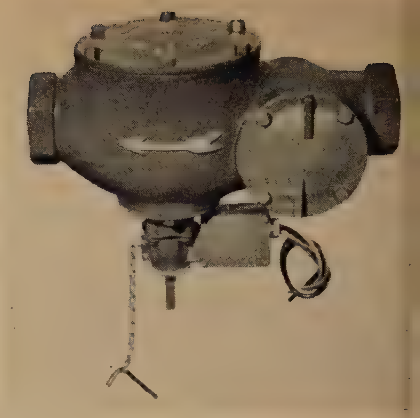

Fig. 113 (b). Automatic fire check completely assembled and including a signal switch (*Courtesy of Selas Corporation of America, Philadelphia, Pa.*)

fails on the mixer and compressing equipment, the closing of the valve in the fuel-gas line prevents the possibility of leakage of raw fuel through the equipment and into the furnace.

Fire Checks

When a gas-air mixture is premixed and piped to the burners under pressure, it is customary practice to protect the distribution line and mixing equipment with fire checks placed just ahead of the burners. Such devices use the principle of high velocity through very small ports to arrest the travel of flame and maintain it at the fire check, thus preventing its traveling back to the compressor. Fig. 113 illustrates a typical automatic-type fire check. In addition to the flame-arresting screen which can be seen in Fig. 113 (a), the device contains a built-in spring-closing-type valve which is held in the open position by two bimetallic strips on the top side of the screen. In the event of a backfire, the flame would be arrested at the top of the screen where it would heat the bimetallic strips sufficiently in a few seconds to release the valve stem and permit the valve to close, thus shutting off the flow of air-gas mixture ahead of the fire-check screen. This device also incorporates a check valve, which can be seen partially removed from the side of the unit in Fig. 113 (a) and which, in the case of an explosive back-fire, would close momentarily before the flame traveled to the fire-check screen, thus insuring that the force of the explosion would not drive the flame through the screen. This is an important feature and is required to give complete protection when handling high-hydrogen gases, such as coke-oven gas.

Fig. 113 (b) illustrates the assembled unit and shows the manual reset stem of the valve projecting from the bottom. Also incorporated in this unit is an electrical switch which can be used to operate an alarm circuit or to stop the compressing unit.

Flame-failure Devices

Flame-failure devices are available which utilize electronic circuits and operate on the principle that flame is a conductor of electricity. Such devices are in general use on low-temperature air heaters and ovens where ignition is dependent on a pilot burner. Such devices, however, are not generally used on atmosphere generators and are not recommended by the fire insurance underwriters. There are two reasons for this: the first is that the generators utilize refractory-lined combustion chambers which operate at temperatures of 1800 F or higher and serve as a constant source of ignition that eliminates the need for a pilot; and the other reason is that the device does not operate until complete flame failure occurs, which means that the ratio of gas to air could vary widely, permitting the equipment to operate while producing products of combustion high in combustible gases, or even containing a considerable amount of free oxygen before flame failure would take place. For inert-gas-producing equipments particularly, the protective device should guard against the production of a gas containing more than very small amounts of either combustibles or free oxygen. More complete protection is afforded by the use of continuous analyzers in the output gas (Part VIII) which can operate signal devices or shut down the equipment by means of electrical switches actuated by the instrument when the analysis goes above or below the set range.

Fig. 114. A typical solenoid-type valve that is opened when energized (*Courtesy Automatic Switch Corporation, Orange, N. J.*)

Furnace Protective Devices

Solenoid Valves. As previously mentioned under Principles of Purging, it is hazardous to introduce a flammable gas into a furnace chamber (containing air) which is not up to ignition temperature (1400 F). To prevent the accidental occurrence of such a situation, automatic means can be provided for closing the atmosphere line to the furnace chamber until that chamber has reached the proper temperature.

One simple method of accomplishing this is to place a solenoid-operated valve (Fig. 114) in the atmosphere line to the furnace which will remain closed until the solenoid is energized. By means of an extra set of contacts on the temperature-control instrument for the furnace, this valve will become energized and opened only after the temperature of the furnace reaches 1400 F. If the furnace chamber has an attached cooling chamber into which some of the furnace atmosphere is normally introduced, then a second solenoid valve will be required in the atmosphere line to the cooling chamber. This solenoid valve will be actuated through a time switch which is started at the instant the atmosphere is automatically introduced into the hot chamber. After sufficient time has elapsed in which to safely purge the furnace and cooling chamber by means of the atmosphere which enters the hot chamber, the timer will close the circuit to the valve in the cooling-chamber line and allow atmosphere gas to enter at that point as well as into the furnace chamber.

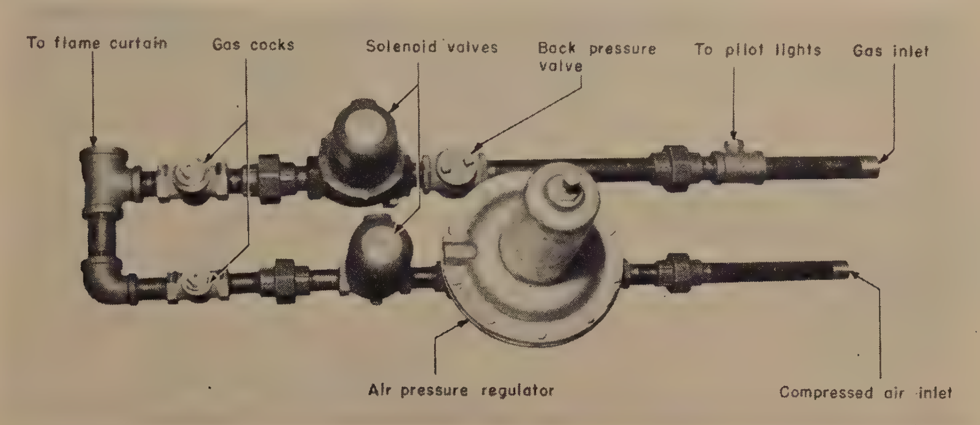

Fig. 115. Piping arrangement of pressure regulator and valves for supplying a mixture of air and gas to a flame-curtain burner such as that shown in the Frontispiece

Flame Curtains. Practically all atmosphere furnaces utilize flame curtains at the entrance and exit doors, for the purpose of preventing the entrance of air from the room and retarding flow of atmosphere from the furnace, when the doors are opened. The curtains employ either raw gas or a mixture of air and gas, generally distributed across the bottom of the furnace opening in such a manner as to permit the flame to completely cover or shield the furnace opening.

The burner itself is generally a pipe with a row of closely spaced small holes, or small burner tips placed close together and of sufficient length to more than cover the width of the door. A typical gas curtain such as that shown on the Frontispiece illustrates the effectiveness of coverage of a door opening 27 in. wide and about 10 in. high. Continuously burning pilot lights can be seen at each side of the door which serve to ignite the curtain when the door is opened. Such curtains are usually arranged to turn on and off automatically when the door is opened or closed by either mechanical or electrical means.

Curtains of this type usually employ a gas-air mixture adjusted to about 50 percent aeration which produces a clean, clear flame that does not interfere with visibility. The curtain illustrated is supplied with a gas-air mixture obtained by mixing compressed air with coke-oven gas. The simple arrangement of the equipment for this method is shown in Fig. 115. The compressed air is reduced to a low pressure so that its flow can be readily controlled. The fuel-gas line includes a back-pressure or check valve which will prevent any accidental backing up of compressed air into the fuel-gas line. The two gas cocks are used for adjusting the flow of air and gas to give the proper mixture at the mixing tee from which a pipe conducts the mixture to the burner at the front of the furnace. The two solenoid valves open or close both lines simultaneously by means of a switch actuated by the furnace door.

To properly cover door openings greater than 12 in. in height it is advisable to increase the fuel-gas pressure considerably above the 8 in. water normally available. Sometimes it has been found advantageous to supply the proper mixture from a premix equipment, with motor-driven compressor, which can supply the mixture at pressures from 1 to 3 lb per sq. in.

(To be continued)

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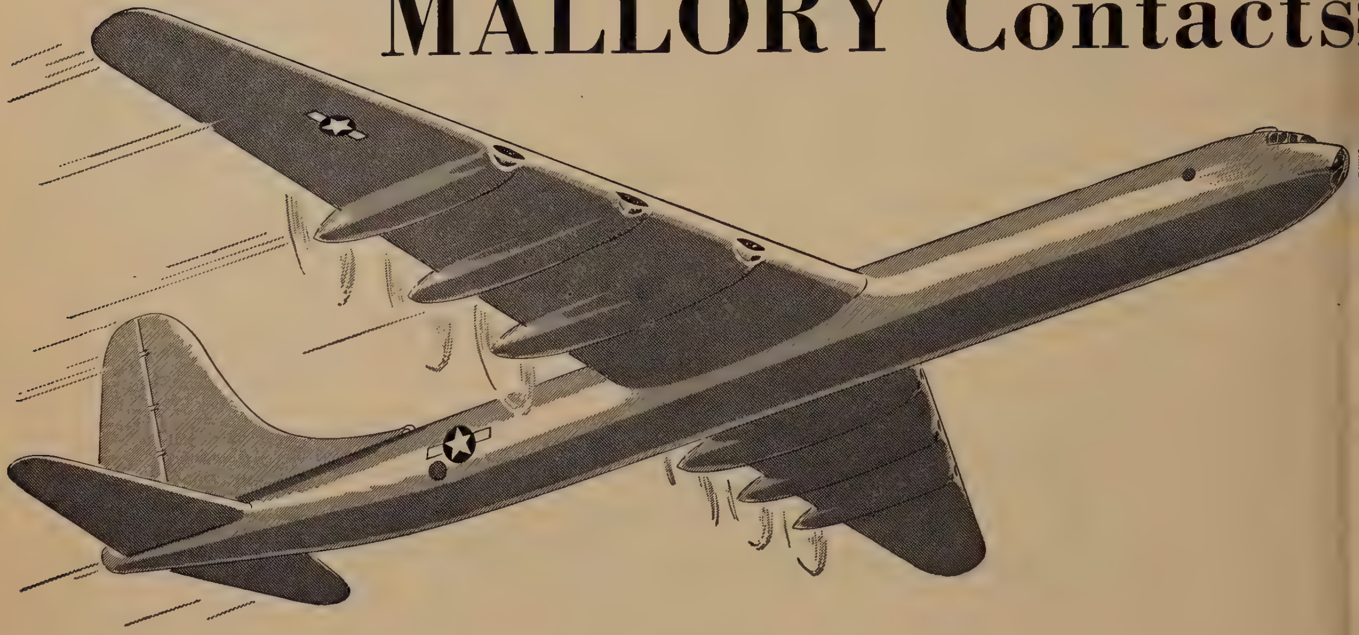

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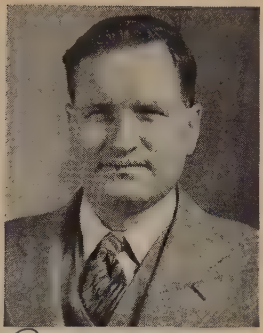
VERSATILE, INKLESS, MULTICHANNEL RECORDER

Tests made on a commercial air line indicate the utility and reliability of this system of continuous recording of significant operating conditions

By D. W. HALFHILL
Meter and Instrument Divisions, West Lynn Works
General Electric Company



D W Halfhill

THE need for an adaptable recording system capable of remotely registering nonelectrical, as well as electrical, quantities has long been realized. Though individual recording problems have been solved in specific cases and with varying degrees of success, a single device adaptable to the recording of many different entities such as pressure, electrical quantities, temperature, and mechanical motion has not been readily available.

An answer to many of these problems may be found in a recording system recently developed for a flight-recorder program which required that barometric altitude and vertical acceleration forces be logged continuously by passenger-carrying airplanes. A number of unusual features have been included in this recording system which may prove useful outside the field of aviation.

The inherent flexibility of the system allows the recording of almost any quantity, merely by attaching appropriate primary detectors. Features peculiar to the system described here are:

(1). Continuous recording without the use of ink, ribbon, or other recording means having similar limitations. This is made possible by a pressure-sensitive chart paper, to be described here. The record is immediately available as a fine-lined legible trace, regardless of ambient temperature or pressure conditions.

(2). An endless-belt system which permits multiple traverses of the chart without interruption. A scale expansion greatly beyond the width of the chart is therefore possible, and uninterrupted records of continuously rotating functions, such as wind direction or compass heading, may be accurately recorded.

(3). A telemetering principle permitting remote location of the intermediate means and end device from the primary detectors.

(4). Two recording channels for continuous functions and two for "on-off" indications. This makes possible simultaneous comparison of four separate functions on the same strip chart.

(5). Light, sturdy, shock-mounted construction, which permits use where more delicate instruments would fail. Furthermore, since accuracy is not affected by shocks or jolts to the recorder, mobile use is possible.

DESCRIPTION OF RECORDING SYSTEM

Four separate parts make up the complete recording system: an amplifier, a recorder, and two signal transmitters, connected by appropriate wiring. Interconnection of the separate parts is shown functionally in FIG. 1; in order to simplify the diagram, only one signal transmitter is shown. Each of the two recording channels operates independently as a closed-loop servomechanism operating on a null principle. When an angular displacement exists between the recording unit and one of the detectors, an error voltage representing that displacement is produced which, when amplified, causes the associated recording motor to drive the unit into correspondence. Therefore, any motion of the primary detector is faithfully followed by the scribing mechanism.

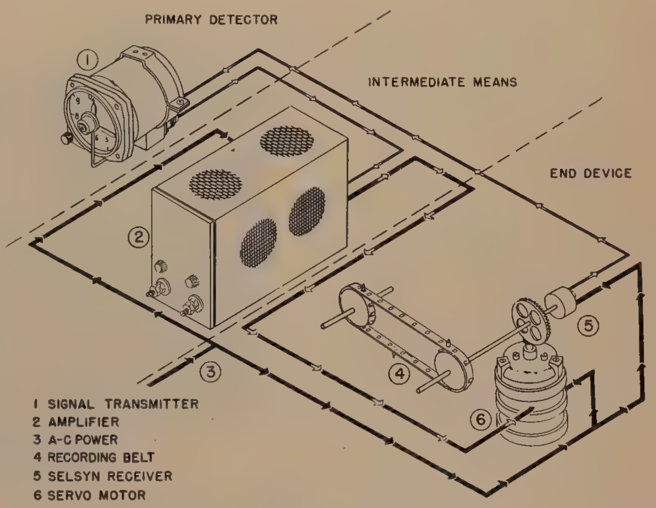


Fig. 1. Functional diagram of interconnections to one channel of the recorder

The two sensing devices used in the system consist of primary detectors producing a rotational output coupled to selsyn-type electric transmitters. These units can be mounted at the points where measure-

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This article is so paged that, without mutilating other articles, it can be eadily removed for filing as a group of full-size consecutive pages.—EDITOR ments are to be made. Two types of signal transmitters are shown in FIG. 2. The unit on the left is specifically designed to be used with this recording system and can be manufactured where quantity use justifies tooling. The unit on the right consists of a conventional indicating instrument with a small electric transmitter linked to the moving element. This type can be used where small quantities are required. Indicating instruments which produce a torque of 0.2 gram-millimeters or more can be used in transmitters such as these.

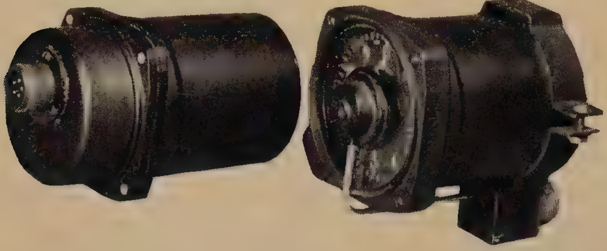
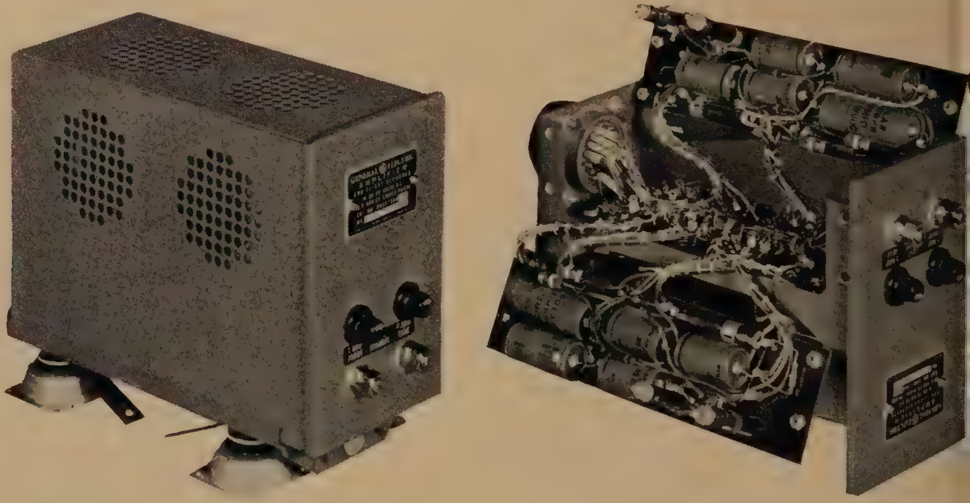


Fig. 2. The two types of transmitting device used with the recording system. Left, special unit with internally mounted selsyn transmitter. Right, conventional indicating instrument with external transmitter

A separate unit consisting of two amplifier channels with a common power supply is also a part of the system. It is small and shock-mounted, uses standard vacuum tubes, and is designed for ease of servicing. Two views of the amplifier are shown in FIG. 3. On the left is a unit with two screwdriver controls for adjustment of the amplifier sensitivity in each channel for optimum operation. On the right, the case is removed and the terminal strips are detached to show provisions for servicing.

Fig. 3. Amplifier unit in its case, at left. Ease of servicing is demonstrated by the opened unit at right



Since each amplifier channel operates as a part of a closed-loop servo system, accuracy is independent of tube characteristics. The amplifier unit serves also as a junction box for the complete recording system.

The recorder (FIG. 4) utilizes a pressure-sensitive chart paper on which a trace is made by drawing a pointed stylus over the surface, producing a fine black line on a white background. The chart itself consis of a paper base on which two coatings are placed– the first black, the second an opaque white. The secon coating is softer than the first, and as the stylus mov across the surface of the paper the white layer is pushe aside, exposing the black layer underneath. Any number of traces may be made on a strip chart of this typ The only limitation is in the number of elements pr vided, in this case four. The system is nonclogging and the styli do not require cleaning. The record wi not fade, and is legible after immersion in either fres or salt water for a considerable period.

Each of the two "on-off" indications is represente by the traces of a stylus at one edge of the paper operated by a magnetic solenoid. When the solenoid are energized, the traces move approximately $\frac{1}{16}$ inc toward the outside edges of the chart. Styli representin continuous functions are mounted on endless belts which run on sprockets as shown in FIG. 5. There ar three styli in each belt, each spaced from the others distance equal to the circumference of one sprocket Thus, continuous rotation in one direction will caus one stylus after another to traverse the chart, each leaving the chart as the next is brought to bear at th opposite end. The record which this produces represent a continuously rotating function. Operation of the system is demonstrated in FIG. 5 where the indicatio of a sensitive altimeter, each rotation of the long pointer representing 1000 feet, is correlated with a multiple trace on the chart.

Two recording belts are necessary; one is located about ⅜ inch behind the other. This arrangement imposes no difficulty, since the distance is always constant, and it has the advantage of separating transient functions for easy examination.

The chart paper is entirely contained in a separate assembly, which can be removed from the recorder t facilitate servicing. The chart is driven by a 60-cps synchronous timing motor at any desired speed up t several inches per minute. For airborne or mobile use 60-cps power is produced by a hermetically sealed precision vibrator operating from an existing d-c power supply. The door to the recorder is provided with a vibration-proof latch, which will not open by itself, and the entire unit is shock-mounted.

PERFORMANCE

Proof of satisfactory operation under unusual conditions is emphasized by a year-long flight test on a major U. S. air line's DC-4, operating in transcontinental passenger service. Over 2500 hours of satisfactory airborne operation were logged; routine inspections during this period indicated satisfactory operation, and no overhauls were necessary. The first service was the replacement of a vibrator, which normally has a life expectancy of about 2000 hours.

Because of the fact that the system was in flight-recorder service, signal transmitters sensitive to altitude pressure and vertical acceleration were used. The relation between these two quantities is easily seen on the record, since the altitude transmitter causes the stylus to make one traverse across the chart for each thousand feet of altitude, and acceleration has limited travel. Changes in altitude as small as approximately ten feet can be detected. By simultaneous analysis of both the altitude and vertical-acceleration traces, it is possible to estimate the magnitude and duration of vertical air currents and resulting stresses to which the airplane is subjected. In many parts of the record, indications of rough flying conditions have shown very clearly why the pilot found it necessary to alter his original flight plan.

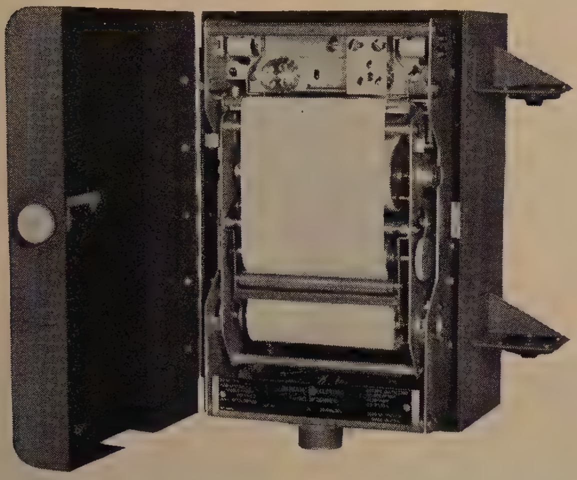


Fig. 4. In the recording unit are two endless perforated belts, each moving a set of three styli across the pressure-sensitive chart paper

One of the "on-off" markers on the air-line test was used to indicate when the autopilot was in operation. Such an arrangement provided a very good check on the sensitivity and performance of the autopilot. Another interesting point was brought out by the flight records. Approaches to one airport were, almost without exception, accompanied by bumps recorded on landing. Airline pilots have verified this condition, saying that it is unavoidable because of a steep approach made necessary by surrounding obstacles. Rate of climb of the airplane is also easy to compute, since a direct comparison of altitude and time scale is possible. Further "reading between the lines" makes it possible to determine when sharp turns are made, because of the displacement in the acceleration record.

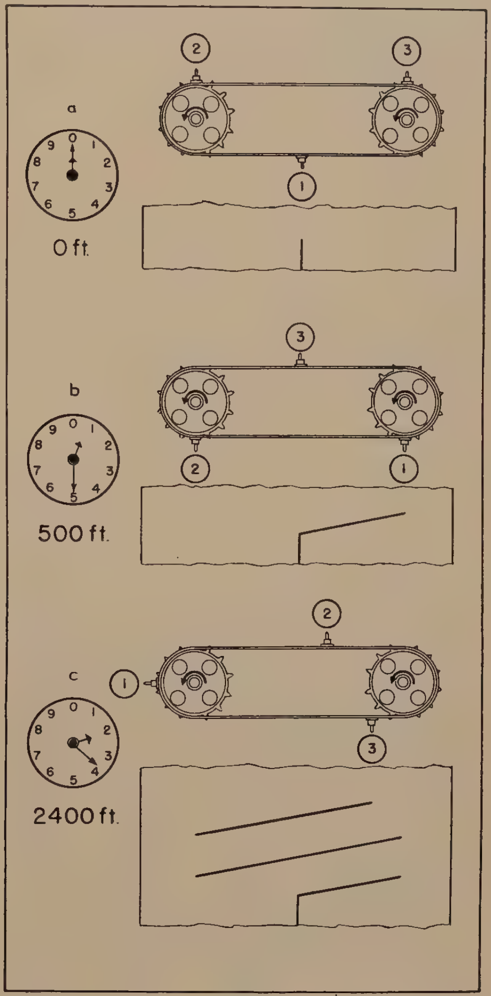


Fig. 5. The multiple-traverse principle correlated with the indication on a sensitive altimeter. Each complete traverse represents a change in altitude of 1000 ft, or one revolution of the long pointer on the instrument

UNUSUAL USES

Because many primary detectors are more accurate than the intermediate means or the end device used with them, a considerable loss of recording accuracy results. With the greatly expanded scale length made possible by the continuous-belt principle, and because of the fact that transmission errors are not cumulative over several cycles of belt revolution, the recorder can take full advantage of the inherent accuracy of the primary detectors. The relatively high speed of response permits recording of periodically changing functions up to three or four cycles per second, depending upon the magnitude of the input and the accuracy required.

While the continuous-belt recorder does not purport to replace oscillographs for recording periodic or transient functions, it nevertheless is capable of operating

(Concluded on following page)

STATEMENT OF THE OWNERSHIP, MANAGEMENT, CIRCULATION, ETC., REQUIRED BY THE ACT OF CONGRESS OF AUGUST 24, 1912, AS AMENDED BY THE ACTS OF MARCH 3, 1933, AND JULY 2, 1946

Of GENERAL ELECTRIC REVIEW published monthly at Schenectady, New York, for October 1, 1949.
State of New York } ss.
County of Schenectady }

Before me, a Notary Public in and for the State and county aforesaid, personally appeared E. C. Sanders, who, having been duly sworn according to law, deposes and says that he is the Executive Editor of the GENERAL ELECTRIC REVIEW and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily, weekly, semiweekly or triweekly newspaper, the circulation), etc., of the aforesaid publication for the date shown in the above caption, required by the act of August 24, 1912, as amended by the acts of March 3, 1933, and July 2, 1946 (section 537, Postal Laws and Regulations), printed on the reverse of this form, to wit:

1. That the names and addresses of the publisher, editor, managing editor, and business managers are:

Name of—	*Post office address—*
Publisher: General Electric Company	1 River Road, Schenectady 5, N. Y.
Executive Editor: E. C. Sanders	G.E. Co., Schenectady 5, N. Y.
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2. That the owner is: (If owned by a corporation, its name and address must be stated and also immediately thereunder the names and addresses of stockholders owning or holding one percent or more of total amount of stock. If not owned by a corporation, the names and addresses of the individual owners must be given. If owned by a firm, company, or other unincorporated concern, its name and address, as well as those of each individual member, must be given.)

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3. That the known bondholders, mortgagees, and other security holders owning or holding 1 percent or more of total amount of bonds, mortgages, or other securities are: (If there are none, so state.)

None.

4. That the two paragraphs next above, giving the names of the owners, stockholders, and security holders, if any, contain not only the list of stockholders and security holders as they appear upon the books of the company but also, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting, is given; also that the said two paragraphs contain statements embracing affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner; and this affiant has no reason to believe that any other person, association, or corporation has any interest direct or indirect in the said stock, bonds, or other securities than as so stated by him.

5. That the average number of copies of each issue of this publication sold or distributed, through the mails or otherwise, to paid subscribers during the twelve months preceding the date shown above is............ (This information is required from daily, weekly, semiweekly, and triweekly newspapers only.)

(Signed) E. C. Sanders
E. C. Sanders, Executive Editor

Sworn to and subscribed before me this 30th day of September 1949.

Dorothy Anne Dumbleton
Notary Public, State of New York
Schenectady County
[SEAL] My commission expires March 31, 1951

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SPECIAL SHEET METAL WORK

MULTICHANNEL RECORDER

(Continued from preceding pag

at frequencies considerably higher than most stri chart recorders not using photographic means.

Primary detectors used in this system need not hav electrical output; therefore, any mechanical, therma or other continuously variable function can be re corded, as well as pure electrical quantities. Conversio to the proper voltages for recording is accomplishe by the selsyn-type transmitters attached to the primar detectors, eliminating the need for developing cor version devices to suit each particular case.

CONCLUSION

Because its light, sturdy construction permits th system here described to be used where other device fail, successful operation is found in marine use, o surface vehicles, and in aircraft. Other uses may b found in industry, where an adaptable recording devic has been needed for some time. Creation of new use can perhaps be effected by those in engineering, pro duction, and development work who have, in the past been limited by the inflexibility of existing measure ment devices. Here, in one tool, is found the means fo successfully recording a multitude of different func tions. It is through the application of such devices a this that the work of men in industry and researc is made more productive.

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HEAVY-DUTY BEARINGS WITH INTERMITTENT OSCILLATORY MOTION

Unique conditions associated with heavy loading and limited motion must be faced in designing the operating mechanisms for circuit breakers. Textolite bearings give good service

Ralph R Bush

By R. R. BUSH

Power Circuit Breaker Division, Philadelphia Works
General Electric Company

FRICTION in journal bearings has been a subject of continued study since the invention of the first machine. Most of such bearings normally operate under conditions of continuous rotation, with intermittent periods of rest; and most of the published literature on the subject is concerned with these conditions. Such bearings normally require rather frequent attention and a supply of lubricant that can be conveniently renewed. This lubricant is continuously carried into the bearing by the rotating action of the shaft in the bearing.

In some bearing applications, such as power circuit breakers, however, no such continuous shaft rotation is present to carry lubricant into the bearing, which may consequently either operate dry or with grease that may be either inserted at assembly or forced in under pressure. Circuit-breaker bearings are different also in that their rotation is confined to a fraction of one revolution in most instances, and operations may be frequent or extremely infrequent. In fact, many operate so infrequently that if the duration of all the operations of the circuit breaker during 20 years service were added together, the total time of operation might easily be as little as a single hour. Seldom would it be greater than 10 hours.

Despite its limited movement, however, which eliminates any possibility of carrying lubricant into the bearings, the circuit breaker must stand ready to operate and interrupt a dangerous short circuit at high speed on an instant's notice. To do so, every bearing in the circuit breaker must operate with a minimum of friction regardless of the length of time which has elapsed since the last operation. Published data on this type of bearing service is practically nonexistent. This does not, however, eliminate the problem—a problem which circuit-breaker manufacturers have studied with each new circuit-breaker design in their endeavor to provide the highest degree of operating reliability.

A power circuit breaker consists essentially of a large switch with means for extinguishing arcs. It has stationary contacts on each phase of an electric circuit connected and disconnected by moving contacts. Generally speaking, springs oppose the closing of the moving contacts and account for a large part of the power required to close them. The quick opening is accomplished by a release or trip that allows the springs to come into play.

Each passing year has seen the duty on circuit-breaker bearings increase, both as regards bearing pressures and bearing speeds. FIG. 1 shows a relatively early type of circuit breaker (with the oil tank removed) rated 2500 volts with an interrupting rating of 15 MVA*. The mechanism operating speeds were comparatively low and the bearing loads relatively light. Simple overload tripping and manual operation were the rule.

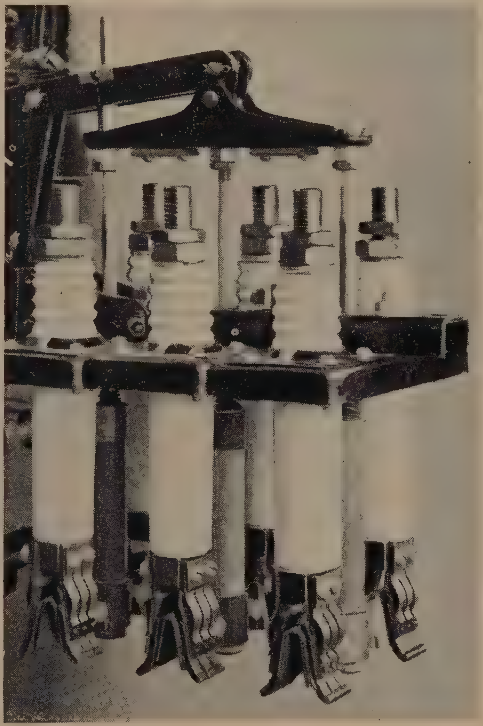

Fig. 1. Oil circuit breaker with tank removed. This breaker of 1925 vintage used brass pins in steel links of its mechanism. Height over-all, 2½ ft

As the electrical power systems grew, however, short-circuit currents increased, and larger and faster

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Presented as a paper at the Erie (Pa.) Meeting of ASME on September 30, 1949.

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

*MVA = Megavolt Amperes = Million Volt Amperes circuit breakers became necessary to prevent damage to valuable apparatus. To obtain maximum continuity of service, circuit breakers were developed to provide high-speed clearing and reclosing of circuits. Fig. 2 shows a circuit breaker recently developed which has a rating of 360,000 volts, 10,000 MVA. It was designed to open its 6 sets of 1000-amp contacts in 0.05 sec and to reclose them in 0.167 sec. As a matter of comparison of size, the inset at the lower lefthand corner shows the early breaker (Fig. 1) to the same scale as this modern breaker. Without the improvements both in circuit-breaker bearing design and in bearing materials which occurred in the intervening years, the latter designs would not have been possible. Fig. 3 represents the general development of these characteristics in a chronological relationship.

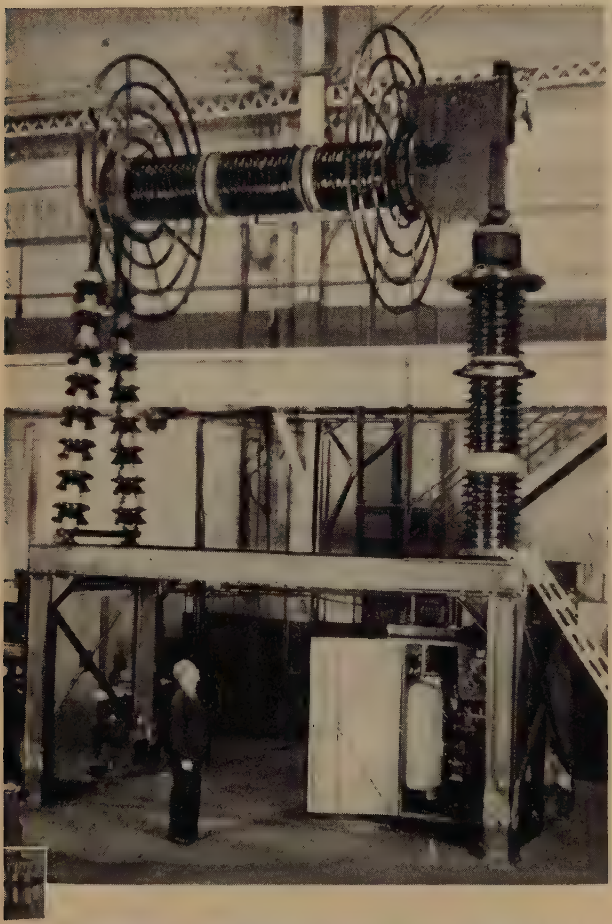

Fig. 2. Low-oil-content impulse-type oil circuit breaker. Rated 360 kv, 10,000 MVA. Interrupting time, 0.05 sec. Reclosing time, 0.167 sec. A modern breaker with modern bearings. Height over-all, 28 ft. Inset (lower left) of breaker from Fig. 1 compares sizes

BEARING REQUIREMENTS FOR THE MECHANISMS OF MODERN CIRCUIT BREAKERS

As previously stated, the operating requirements for circuit-breaker bearings are quite different from those found in most apparatus or machines. This contrast can be illustrated by considering, for example, a motor-generator set (Fig. 4) which develops 50 hp and runs at 3600 rpm. The surface speed of the shaft in the bearings is approximately 35 ft per sec; the bearing are lubricated by oil and run with pressures in the orde of a few hundred pounds per square inch. The surfac speeds on typical circuit-breaker shafts or pins, o the other hand, are less than 10 percent of the shaf speed of the motor-generater set. The loads per squar inch on the circuit-breaker bearings, however, ar many times higher, ranging from 2000 to 10,000 lb pe sq in. of projected bearing area, depending upon th particular application. In fact, peak pressures may g considerably higher than 10,000 lb per sq in. Thes high bearing loads are a result of the heavy sprin forces used to obtain high-speed acceleration of th breaker contacts. Pin and shaft diameters, moreover are kept as small as possible to limit the diameter o the friction circles. A typical application of such bearings is in the mechanism of the magne-blast circui breaker shown in Fig. 5.

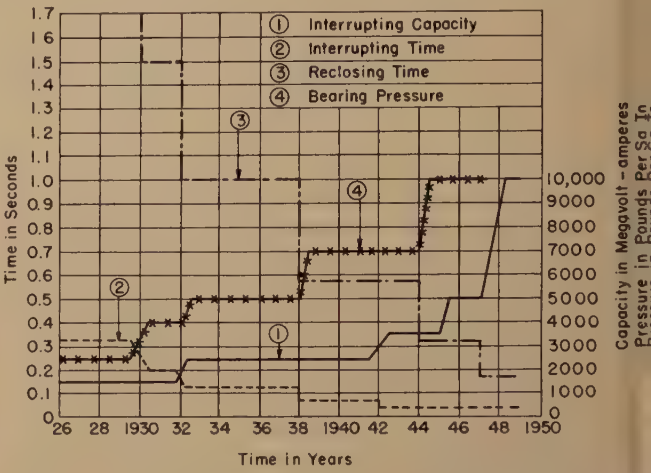

Fig. 3. General chronological development of allowable bearing pressures compared to other power-circuit-breaker characteristics

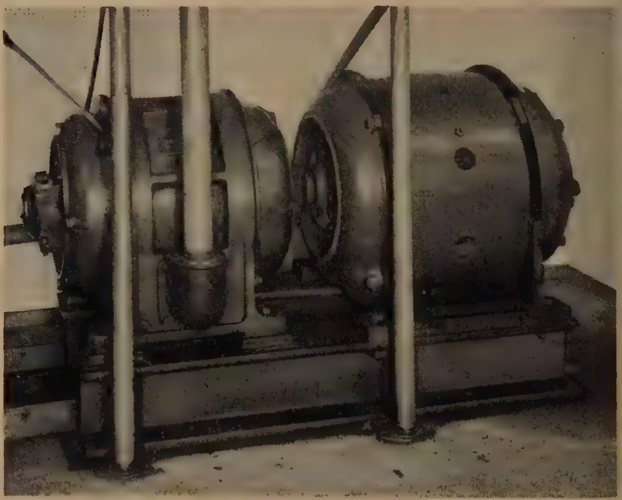

Fig. 4. Motor-generator set for adjustable-frequency output. Rated 50 hp maximum at 3600 rpm. Bearings of such machines must operate continuously at high speed and relatively low loading with oil lubrication.

Most power-circuit-breaker shafts rotate throug limited angles when opened; the majority through les than 60 deg while few rotate more than 120 deg. The closing operation generally reverses through the same angle. Breaker mechanisms consist principally of cranks rotating backward and forward as the breakers close and open. During this motion the load generally varies considerably. As an example, during the closing of a breaker, opening springs and contact springs are encountered in a sequence such that the final forces are anywhere from 5 to 25 times the starting load, depending on the type of breaker. FIG. 6 is a typical force-travel curve at the actuating mechanism of a circuit breaker requiring average operating forces.

Historically, a large combination of materials have been used for circuit-breaker bearings. When circuit breakers were first built for light loads, plain steel pins and steel bearings were usually used. As loads increased, abrasion was encountered and steel pins and brass bushings were substituted. In some cases, it was more convenient to use brass pins directly bearing in steel. FIG. 7 shows an example of bronze pins in both cast steel and malleable cast iron. With the use of nonferrous metal, rusting and corrosion were greatly reduced. The coefficient of friction also was reduced with the use of steel and brass. Later, to reduce corrosion, stainless-steel pins were adopted. When stainless-steel pins and bronze bushings were used, a decrease in the coefficient of friction was again realized.

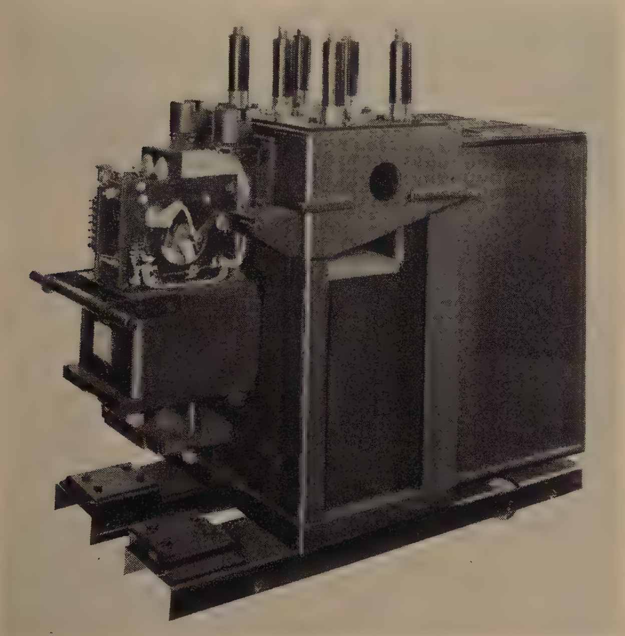

Fig. 5. Magne-blast power circuit breaker. Rated 500 MVA at 15,000 volts. Bearings must operate instantly but intermittently at medium speed and relatively heavy loading. Height over-all, 4½ ft

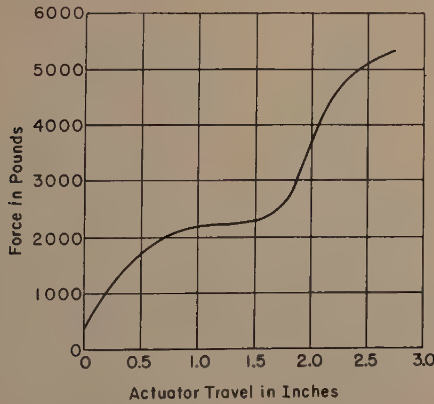

Fig. 6. Typical force-travel curve of circuit-breaker actuator

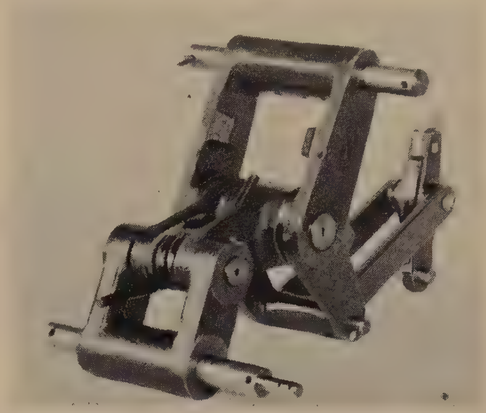

Fig. 7. Solenoid-mechanism linkage using bronze pins in cast steel and malleable cast iron

TEXTOLITE COMPOUND BEARINGS

In the past few years, the number of operations to which some circuit breakers are subjected has greatly increased. A considerable number of new materials have been studied to determine what materials or combinations of materials might be used for circuit-breaker bearings to obtain even lower coefficients of friction, longer life, higher permissible loadings, or less frequent lubrication. For this intermittent duty where heating was not a limiting factor, a much wider range of materials and combinations of materials could be considered than would be possible for continuously rotating bearings.

Of various bearing materials which have been tested, Textolite tubing made of cotton cloth and thermosetting phenolic resin proved far superior to any of the metallic materials. When used with centerless-ground stainless-steel shafts, as illustrated in FIG. 8, this material proved superior to metallic bearings from the followng standpoints:

(1). Its coefficient of friction is appreciably lower than most metallic bearings; moreover, the coefficient of friction decreases as the load on the bearing increases, which makes it particularly desirable for heavily loaded bearings.

(2). Its low modulus of elasticity enables it to absorb extremely high impact loads without cracking or permanent deformation.

(3). Its flexibility permits it to distribute stress over the entire bearing surface even with minor misalignments in the bearing seats.

(4). Its ability to absorb lubricant into the surface of the material reduces the frequency of maintenance for lubrication.

The linkage in FIG. 8 is shown schematically, but more completely, in FIG. 9 to illustrate how the operating forces act through the mechanism and bearings. The heavy arrows show the loadings and the angles indicate the limited motion mentioned earlier.

FIG. 10 shows the test machine used to compare Textolite bearings with metallic and other nonmetallic bearing materials. In this machine any desired bearing load may be obtained. The shaft operates in each direction in a manner similar to the action of a circuit breaker being closed and opened; then it stands at rest 13 sec before the next operation. This allows four operations per minute. FIG. 11 shows an Olsen test machine and compressometer checking the shaft bending and the distribution of bearing loading. FIG. 12 is a close-up view of the bearing mountings in the Olsen test machine.

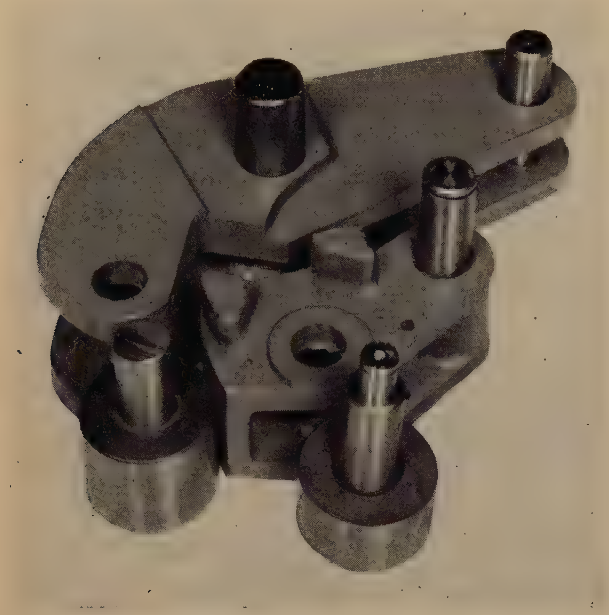

Fig. 8. Cranks and rollers from an air mechanism, showing use of Textolite bushings and stainless-steel pins

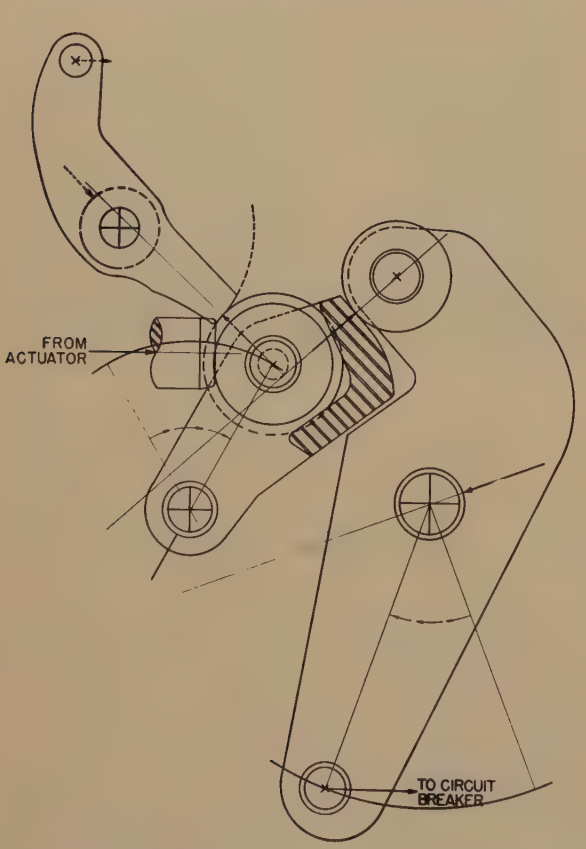

Fig. 9. Schematic diagram of mechanism, illustrating loadings (by heavy arrows) and limited motion (by angles)

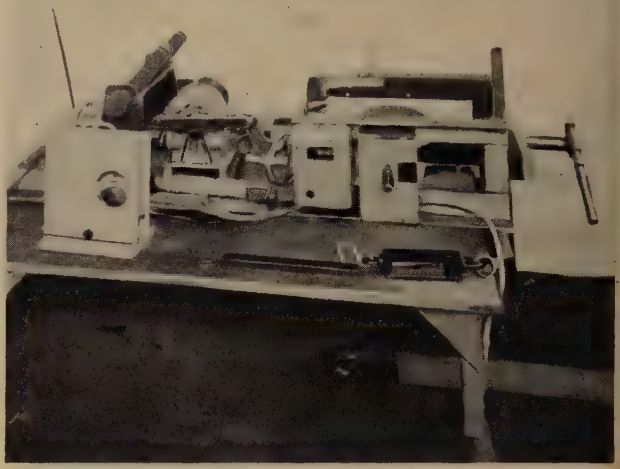

Fig. 10. Bearing test machine for life test and friction measurements

APPLICATION

The advantages which Textolite bearings offer over metallic bearings for circuit-breaker applications have caused them to be used widely during the past few years for all locations except trip latches or other locations where very low torques are available. Ball, roller, or needle bearings have been used at these locations because of their lower coefficient of friction at lighter loads.

Textolite bearings are normally held in place by the press fit between the outside diameter of the Textolite and the diameter of the hole in the supporting member. Because Textolite is a compressible material, considerably more interference between these two diameters can be tolerated than with metallic bearings. A Textolite bearing as much as 20 mils per inch of bearing diameter larger than the hole in the supporting member may be pressed into place without damage to the Textolite bearing providing sufficient pressure is available for the purpose.

As it is pressed into place, however, the compression decreases the internal diameter of the bearing approximately the same number of mils as the interference between its outside diameter and the hole in the supporting member. Consequently, the amount of press fit between the outside of the bearing and the hole in the supporting member must be held to fairly close tolerances to insure uniform internal diameter in the bearing when in place. A clearance of approximately 7 mils is desirable between the internal diameter of the bearing and the shaft to provide for shaft deflection between the two ends of the bearing and also to permit slight expansion during periods of high humidity. The wall thickness is $\frac{1}{8}$ in. for small and medium sized bearings, while a $\frac{3}{16}$-in. wall thickness is used on the larger ones.

The coefficient of friction between the shaft and the bearing depends upon the amount of the press fit which was used when inserting the bearing in the supporting member. FIG. 13 shows curves taken on $\frac{3}{4}$-in. bearings with three different amounts of press fit and with the same grade of lubricant in each case: No. 1 with 3 to 6 mils interference; No. 2 with 8 to 11 mils; and No. 3 with 13 to 16 mils. In No. 1, where only 3 to 6 mils were used, it was found that the shaft sank into the bearing and made contact with considerably more than 120 degrees of its surface. In No. 2, with the 8 to 11 mils press fit, the Textolite material was considerably more compressed thus giving better support, and contact was made over 90 to 120 deg of surface which decreased the coefficient of friction appreciably for all loads. In No. 3, with the 13 to 16 mils press fit, less than 90 deg of contact were obtained and the coefficient of friction was almost doubled. This substantiates a large number of tests indicating that 8 to 11 mils of press fit per inch of the bearing diameter will provide the optimum operating conditions for circuit-breaker bearings. Textolite bearings with this press fit may therefore be used for most circuit-breaker applications.

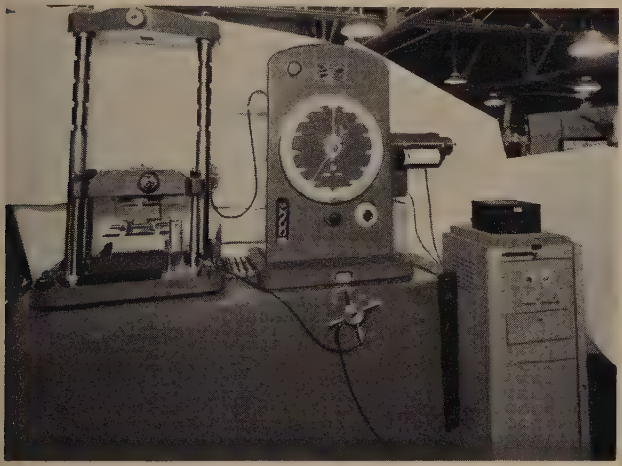

Fig. 11. Testing for shaft bending and bearing loading in test machine

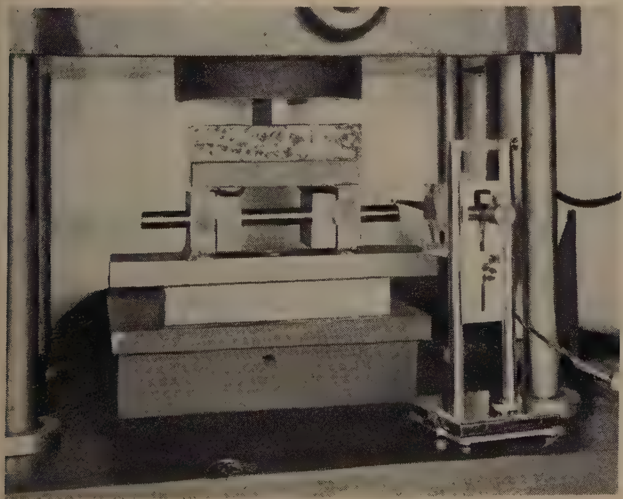

Fig. 12. Bearing mounting in Olsen test machine. Compressometer is tracing shaft displacement under load

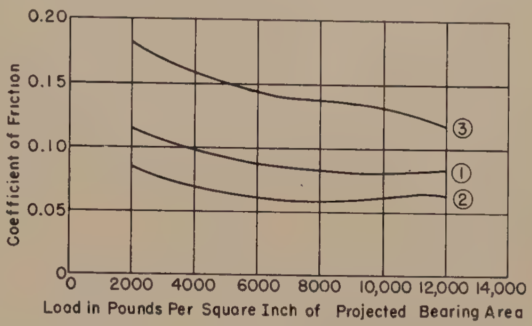

Fig. 13. Friction-load curves with stainless-steel pins in Textolite bushings

(1). Bushing interference fit, 3 to 6 mils
(2). Bushing interference fit, 8 to 11 mils
(3). Bushing interference fit, 13 to 16 mils

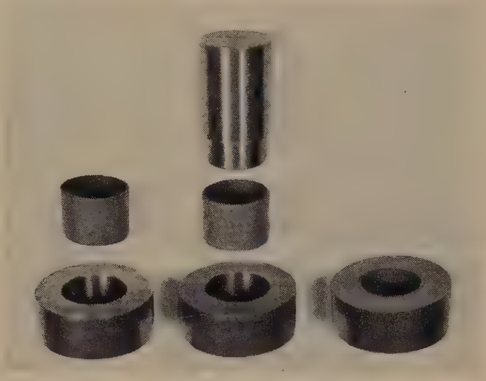

Fig. 14. Textolite bushing assembly

FIG. 14 shows the method of installing these bearings. The hole in the supporting member should, of course, be smooth with a small chamfer on the side from which the bearing is to be pressed into place. This is necessary to prevent damage to the outer surface of the bearing during pressing into place. A small bevel at the ends of the outer surface of the bearings has also been found helpful in eliminating shearing damage during the pressing operation. In most cases the friction of the press fit will hold the bearing in place. If very short bearings are used or if the impact loading is especially severe, it may be necessary to install retaining plates at either end of the bearing to prevent it from working out.

Life tests in actual circuit-breaker bearings show also that considerably higher bearing loads per square inch of projected area are permissible with Textolite bearings than with metallic bearings. Whereas 7 to 8 thousand pounds per square inch of projected area is considered maximum for most metallic bearings, 10 to 12 thousand pounds per square inch may be used

(Concluded on following page)

(Continued from preceding page)

without difficulty on Textolite bearings. This permits the use of smaller shaft sizes, thereby resulting in further reduction in friction and faster breaker operating times.

The Textolite bearings may also be subjected to impact load which in a few operations would elongate metallic bearings beyond further possible use. This is particularly desirable in circuit-breaker applications as it eliminates the necessity of dashpots or other buffing means in many locations, if they were installed primarily for protection of the bearings.

Many locations of circuit breakers are very dirty. Fig. 15 is an illustration of the dirt that might collect on a trip linkage under somewhat normal conditions. In steel mills or cement mills, much worse conditions than this are encountered. The use of grease in sleeve bearings minimizes the effect of dust although washers are often used to protect the ends of the bearings. Textolite bearings are not as adversely affected by foreign matter that may enter the bearing as are metallic bearings. Any foreign matter is embedded rather easily in the Textolite and the scoring action on the shafts is greatly reduced. The bearing itself is not affected. Temperature has little effect on the operation of Textolite bearings unless it rises so high that the strength of the cotton fibers is impaired. If the temperature is raised higher, actual charring will take place. Thi limits the use of Textolite bearings in most application of continuous rotation where the local temperature a the inner surface of the bearing may be quite high unless some means of keeping the bearing cool is provided.(1)

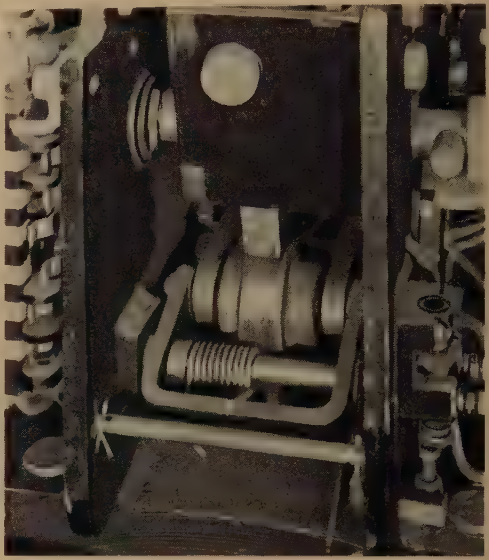

Fig. 15. Trip linkage of a typical circuit breaker in dirty location. Note the dirt piled along lefthand link in the center of the picture

Lubrication has always presented a problem in circuit breakers. Without complete rotation and continuous rotation, little grease is drawn into the bearing as it operates; therefore, the only lubrication that can be depended on is that which is inserted at assembly Textolite bearings are made from a cloth embedded in phenolic resin. The spaces in the cloth are seldom entirely filled with the resin on the inner surfaces. The little pockets which are left retain grease much more readily than smooth metal finished surfaces. This appears to explain to a great extent why Textolite bearings operate so satisfactorily under the very heavy loadings on power circuit breakers.

CONCLUSIONS

The rather unique requirements for circuit-breaker operation have resulted in a type of bearing investigation somewhat different from that undertaken by industry in general.

The Textolite bearing has given very dependable service on intermittent operation under heavy loads Friction is less than for other types of bushing bearings Resistance to impact is remarkable on account of the low modulus of elasticity or springiness of this material Corrosion is practically nonexistent when Textolite is used with stainless steel shafts, and the lubrication problem is eased—all of which simplifies the maintenance problems and insures dependable operation o power circuit breakers.

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(1)"Laminated Plastic Bearings for Heavy Duty and Severe Service," b E. P. Littlefield, *Product Engineering*, vol. 20, No. 1, 1949, pages 111-11 inclusive.

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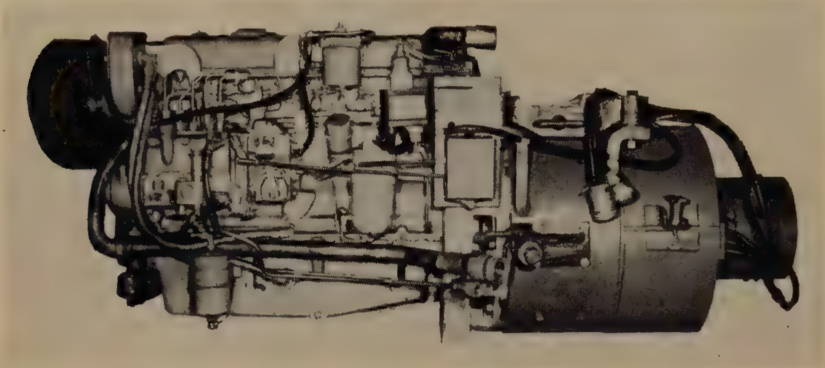
HIGH LIGHTS AND SIDE LIGHTS

Undercar Power Plant

A new diesel-electric undercar power plant for railway passenger-car auxiliary power has been developed. Rated 30 kw, the unit is designed for mounting underneath any new or rebuilt passenger car with sufficient clearance to allow unrestricted movement on any railroad in the United States.



Diesel engine-generator unit for the undercar power plant

The power plant consists of a 50-hp diesel engine and an alternator that provides 220-volt three-phase 60-cycle power. The 4-cycle engine has a displacement of 273 cubic inches. The alternator has a maximum gross rating of 33.8 kva and, with its ultrahigh-speed amplidyne exciter and static-type regulator, has been designed to handle the present-day car loads with power to spare.

One of the major advantages of this type of plant is the elimination of the load on the locomotive that is produced by axle-driven generators. It has been estimated that as much as 20 percent of the load on a passenger-train locomotive under limiting conditions of acceleration will be the axle-generator drag. Faster train schedules and longer trains will be possible when the diesel power plant is applied.

Although the diesel-driven set weighs 4800 lb, the elimination of the batteries, cable, air-conditioning motors, and drive unit necessary with an axle-driven generator make the diesel-driven set lighter than the conventional undercar power plant. A unique mounting arrangement makes maintenance easy by enabling the equipment to be swung out of its sound-insulated box and out from under the car.

The power plants have been designed to operate in parallel so that an entire train can be train-lined, thus assuring maximum reliability. The alternators are so designed that no synchronizing equipment is needed to parallel the sets.

Another advantage of the sets is the relief that can be given the diesel-electric locomotive steam boilers. The 30-kw diesel generator not only affords about 20 kw of electric heat but also makes available a large supply of potential heat in both the engine-jacket water and the engine exhaust. It is estimated that an efficient car-heating equipment will be able to recover about 18 kw of exhaust heat and about 25 kw of waste heat from the jacket water. This means about 214,000 btu total heat per hour available for heating the passenger car.

Exposure Meter Developed For Print-a-minute Camera

A new matchbox-size exposure meter, designed for use with the "print-a-minute" camera, is being produced in quantity.

This instrument is calibrated in numbers from 1 to 8, to correspond to the settings on the new type of camera. Because it does not have a calculator marked in f-stops and shutter speeds, it is not suitable for use with conventional cameras unless a conversion table or special calculator is used.

The new meter can be used to measure scene brightness over a range of 12 to 1600 candles per sq ft. The various film speeds are set by rotating the dial to the letter the film being used.

Weighing only two ounces, the mete comes equipped with a clip which permi it to be mounted directly on the camer Its case, molded from fiber-impregnate plastic capable of withstanding hig shock, is designed to keep out dirt an moisture for increased life and accuracy.

The instrument has a sharply direc tional quality to eliminate the need fo shading the meter.

Cable Provides Radiant Heat fo Chick Brooding

The use of heating cable installed i poultry-house floors to provide radian heat for chick brooding has resulted in material reduction in chick mortality.

In recent applications of the ne principle on poultry farms throughout th Northwest, the chick mortality rate usually ranging between 5 and 10 percent has been cut to an average of about on percent.

This reduction in mortality is du mainly to two things: by even distributio of heat over the entire floor area, th crowding of chicks is eliminated; an because the litter in the poultry hous remains dryer when the cable is used, th disease problem is decreased.

In a typical installation the cable i placed in the top half-inch of the cemen floor, usually over a cinder fill or equiva lent to reduce heat losses downward Used in 60- or 120-ft lengths, it is space at 4-in. intervals to produce approximate ly 70 Btu of heat per square foot of floo space. Depending upon the length o cable used, it is connected to a 115- o 230-volt supply through a thermostat, th bulb of which is buried in the cement. Th cost of electricity has been estimated a approximately two cents per chick.

Even heat from a cable installed in the floor keeps chicks from crowding

Special exposure meter

Isotopes as Tracers

Radioactive isotopes are now being used to trace the progress of new oil shipments as they travel across the country through the Big Inch pipe line.

This is a recently disclosed example of the increasing use of isotopes as tracers in scientific and technological research as well as in industry. In such cases minute amounts of radioactive material are mixed with natural material, and the radiations given off by these radioactive atoms can be measured.

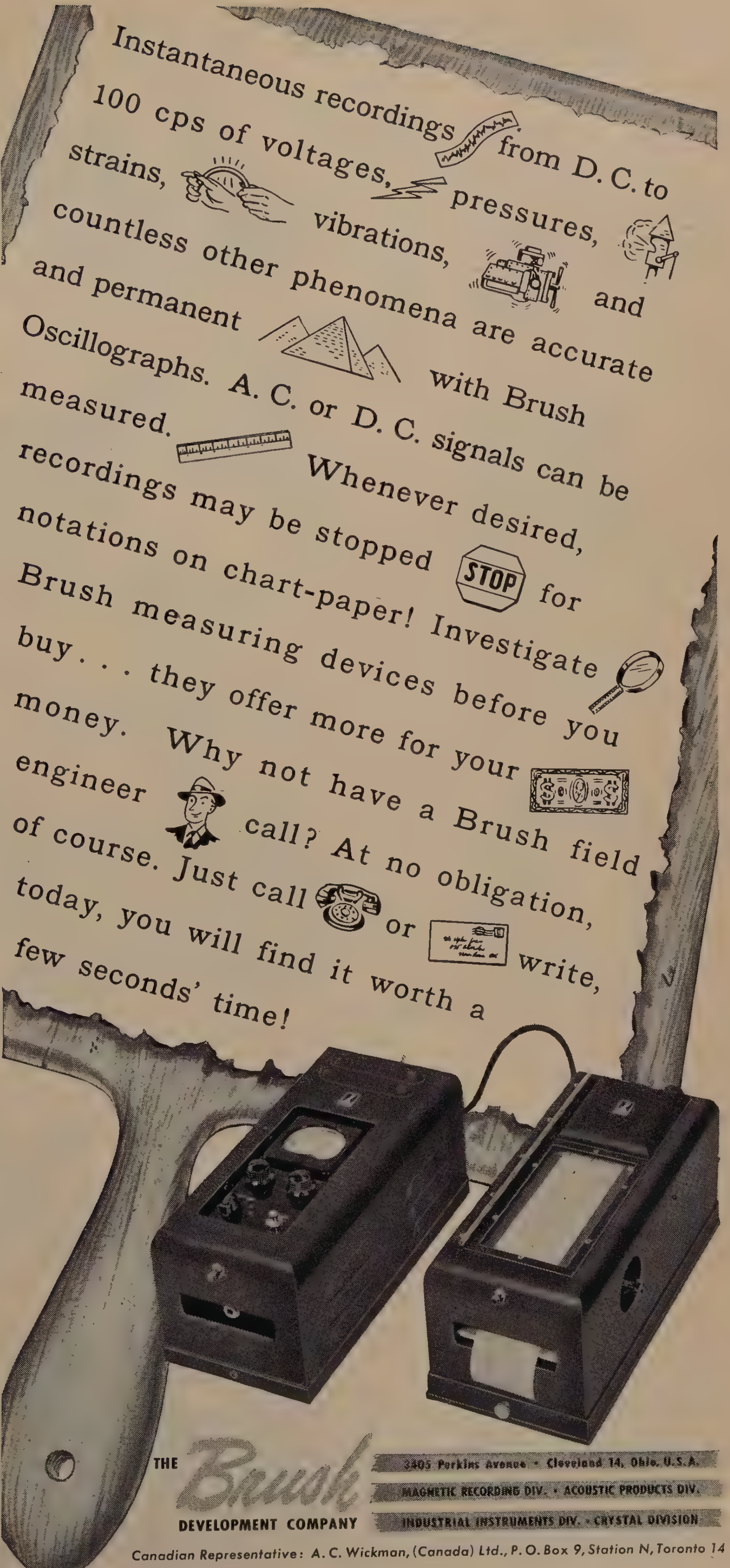
By this means, food assimilation, the penetration of fertilizers, the vulcanization of rubber, the flow of oil, and the synthesis of gasoline are but a few of the processes which can be examined in detail to reveal what is happening within the material or its container.

An interesting deduction can also be made from the ratio of isotopes found in nature under different conditions. The age of the earth—about two million years—has been estimated by the measurement of the relative amounts of the different lead isotopes that occur in rock samples which geologists know to have been undisturbed since they originally solidified on the earth's crust.

Although isotopes as such are found everywhere, the fact that scientists can now make new isotopes of every element and can use these new isotopes in ways that were impossible for the old ones is most important.

These radioactive isotopes are made by a process of transmutation from one element to another, generally by irradiation in a cyclotron, or in a nuclear reactor such as the pile at Oak Ridge.

In addition to giving aid in fundamental research and in certain industrial uses, radio-isotopes have some use in the treatment of certain disease conditions, as their radiation tends to discourage cell growth. At present, however, the therapeutic uses of radio-isotopes appear to be minor compared to their research uses.



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NEW PRODUCTS: AND WHAT THEIR MAKERS HAVE TO SAY ABOUT THEM

Power Unit

The Electrothrust all-electric power units designed for use by machine and equipment manufacturers. These units are capable of applying pressures up to several tons for operations requiring pressure, impact, or both, and models are available which offer strokes from a fraction of an inch to several inches in length. The units, of cylindrical cast electrical steel construction, are easily mounted, and operate from any a-c lighting circuit.—*Black & Webster, Inc., 30 Pleasant St., Needham 92, Mass.*

Emulsion Pellicles

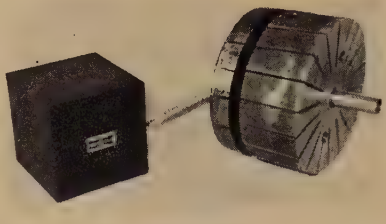
Nuclear track photographic emulsion NTB3 is now available in pellicle form without the usual glass support. The pellicles permit an emulsion thickness of approximately 250 microns without the problem of uneven development, which is encountered when emulsions of this thickness are coated on glass or other supports. Since the solutions work on both sides of the pellicle, development is no more difficult than is that of supported emulsions of approximately half the thickness. The pellicles obtainable in three sizes can be exposed in a vacuum without fracturing and are characterized by reasonable flexibility. The emulsion is sensitive to alpha particles, mesons, protons, deuterons, and electrons.—*Eastman Kodak Co., Rochester 4, N. Y.*

Temperature Test Chamber

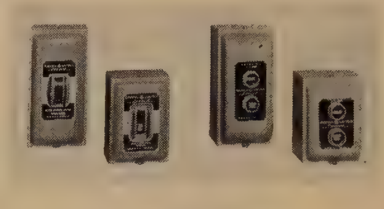
A compact, economical, and convenient temperature test chamber, Model TC-1, for the rapid performance of ambient temperature tests. It was especially designed for individual research workers, the small laboratory unit, and production-line tests of all types of small products. The portable and self-contained chamber is suited to the performance of ambient-temperature variation tests on basic instruments, electronic subassemblies, components and small equipment, foods, textiles, paints and dyes, organic materials, plastics, rubber, etc. Cooling within the chamber is done by carbon dioxide ice, and heating is accomplished by a high-capacity strip heater. Forced circulation of air takes place constantly. Thermostat control, balancing heat against dry ice evaporation, permits any temperature to be maintained between −65° and +275 F.—*Statham Laboratories, Inc., 9328 Santa Monica Blvd., Beverly Hills, Calif.*

Mechanical Sampling Device

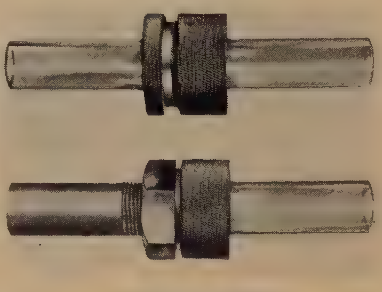
A high-speed mechanical sampling device providing clean and reliable switching at sampling rates up to and exceeding 5000 cycles per minute. Sixty make-before-break contacts are sampled during each cycle. Switches with 30 contacts are available with even higher sampling rates. The switch is so designed that it can be driven by an external shaft, thus permitting direct synchronization of electrical circuits with mechanical motion. The device can also be furnished in one unit with driving motor of any design or speed within the stated limits.—*Applied Science Corp., P.O. Box No. 44, Princeton, New Jersey.*



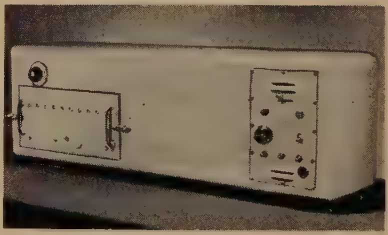
Power Unit



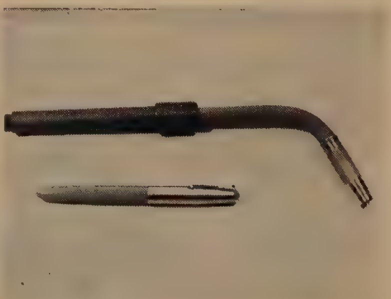
A-c Starters



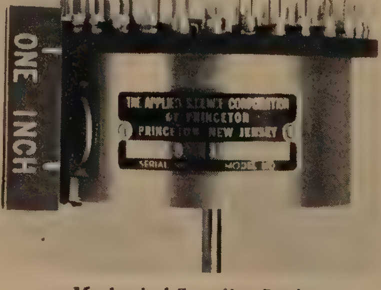
Glass-pipe Couplings



Temperature Test Chamber



Inert-arc Electrode Holder



Mechanical Sampling Device

A-c Starters

A new line of manually operated starters for a-c motors up to 7½ hp. These starters are specially designed for use on farm machinery; textile looms; and small pumps, blowers, and grinders. They are furnished in both toggle and push-button types in 2-, 3-, and 4-pole forms, size 0 and 1. The toggle-operated types in the same forms and sizes are also furnished, if desired, with cast-iron enclosures for use in wet, dust-laden, or hazardous locations. Bimetallic overload protection replaces the solder-pot relay and provides exceptionally accurate response to overloads. In addition, the starters are equipped with a wide range of heaters which are enclosed in a cavity in the molded base, thus providing maximum protection to the operator in the event of short-circuit.—*General Electric Co., Control Divisions, Schenectady 5, N. Y.*

Glass-pipe Coupling

A new threaded metal coupling for use with Pyrex glass-pipe lines. The coupling greatly simplifies the installation of glass piping by replacing three-bolt triangular metal flanges. The use of wrenches is no longer necessary, and desired alignment is assured. The danger of breakage due to uneven take-up is eliminated. These metal couplings are available in sizes ¼ in., ½ in., ¾ in., and 1 in. for making glass-to-glass or glass-to-metal connections.—*Fischer & Porter Co., Hatboro, Pa.*

Rope Swivel

A new type of wire rope swivel that has double roller bearings and will swivel under full load. The unit was originally developed for use by utility companies and is now being offered for all rope applications. Some of the features of these swivels are: both thrust and radial roller bearings; completely streamlined bodies; heavy load capacity in relation to size; permanent lubrication; replaceable parts. These swivels are offered in five sizes from ½-in. to 1½-in. wire rope sizes. They are also equipped with four types of ends: eye-bolt, hook-bolt, integral-eye, or clevis.—*Flexo Machines Co., 456 N. Aberdeen St., Chicago 22, Ill.*

Inert-arc Electrode Holder

A miniature inert-arc electrode holder, featuring a flexible front-end assembly made of malleable copper tubing surrounded by a sheath of silicone rubber so that it can be bent in any direction to reach hard-to-get-at places. Specifically designed for the fluxless welding of nonferrous metals in the thinner gages from No. 16 to No. 40, the holder is available in two models: One for 0.010- and 0.020-in. tungsten electrodes and the other for 0.040- and $\frac{1}{16}$-in. tungsten electrodes. It has a rating of 40 amp continuous, and can be used with either a-c or d-c supply. Currents as high as 60 amp can be used if overheating is prevented by low duty cycles. Small, light, and adaptable, this welding tool will find application in the manufacture and repair of surgical instruments, cutlery, business machines, control and measurement equipment, etc. It should be useful also to manufacturing jewelers and in model building and laboratory apparatus construction.—*General Electric Co., Welding Divisions, Fitchburg, 8, Mass.*

High-voltage test sets

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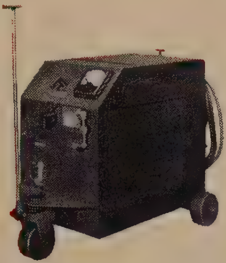
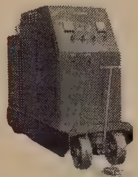
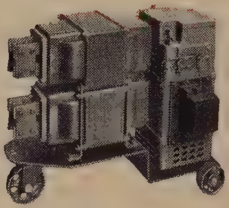
These are popular units!



HIGH POTENTIAL. To 150,000 volts in stepless increments. Operates from 230 v.



HIGH CAPACITY. 300 kva, 30,000/60,000 volts is a widely used set.



HIGH CURRENT. A typical rating is 4000 amperes, a-c. Operates from 115/230 v.

Stationary?

These are suitable for larger installations!

POWER SOURCE. A complete 20-kv, 2-kva tester, for general-purpose testing. Also available in other ratings.

GLOVE-TESTING CABINET. Used with power source, for simultaneous testing of six rubber gloves at 20 kv.

HIGH POTENTIAL. Rated 350,000 volts, 1000 kva, this unit can be cascaded for even higher voltages.

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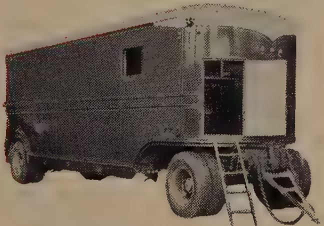

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TRADE LITERATURE

Arc-welding Accessories—Descriptions, specifications, and prices of more than 150 arc-welding accessories are given in a new bulletin. It includes information on electrode holders and carriers, helmets and goggles, tungsten electrodes, protective aids of all types, cable connectors, brushes, cleaning tools, and many other accessories for the arc-welding operator. Twenty pages. GEC-253A.—*General Electric Co., Schenectady 5, N. Y.*

Drafting Device—An illustrated booklet describing the standard Drafter, a precision machine with touch control and Equipoise mechanism. Contains detailed drawings of 38 scales for use with the Drafter. Four pages. Bulletin A-1062.—*Charles Bruning Co., Inc., 4754 Montrose Ave., Chicago 41, Ill.*

Induction Regulator—Describes Inductrols, a miniature type of voltage regulator, motor operated for manual or automatic control. Construction features, advantages, and applications in the smaller electric apparatus field are itemized with accompanying illustrations. Twelve pages. GEA-4508. —*Apparatus Dept., General Electric Co., Schenectady 5, N. Y.*

Insulation—An introduction to fourteen fabricated slot insulators which include plain, scored, cuffed, and formed styles. Suggestions given for selecting right material. Eight pages.—*Insulation Manufacturers Corp., 565 W. Washington Blvd., Chicago 6, Ill.*

Lighting—A booklet containing useful information about a custom-fitted pattern lighting system, known as Module, which embodies the principle of uniform lighting units and its advantages. Illustrations show how the modular pattern is best suited for effective and economical installation. Twenty pages. Catalog No. 360.—*Mitchell Manufacturing Co., 2525 Clybourn Ave., Chicago 14, Ill.*

Motorized Centers—A versatile new grinding attachment for use on surface grinders, jig borers and grinders, drill presses, and light milling machines is described. Action photographs show many of its uses. Four pages.—*Moore Special Tool Co., Inc., Bridgeport 7, Conn.*

Pumps—A description of opposed impeller pumps available in pressures to 1000 psi suitable for boiler feed, refinery, pipeline, mine drainage, water supply, descaling spray, and general hydraulic service. Two- and four-stage units are illustrated, and rating and dimension tables are given. Twelve pages. Catalog 1550.—*DeLaval Steam Turbine Co., Trenton 2, New Jersey.*

Radiation Counter Tubes—Concisely provides numerous types of operating data on all the latest models of a line of self-quenching radiation counter tubes which include alpha, beta, gamma, and x-ray counters. Eight pages.—*Amperex Electronic Corp., 25 Washington St., Brooklyn 1, N. Y.*

Reflectors—A listing of a complete line of porcelain enamel and Ultranamel reflectors which also introduces three new groups: outlet-box, deep-bowl, and high-bay type units. Four pages. Bulletin 123.—*Steber Manufacturing Co., Broadview, Ill.*

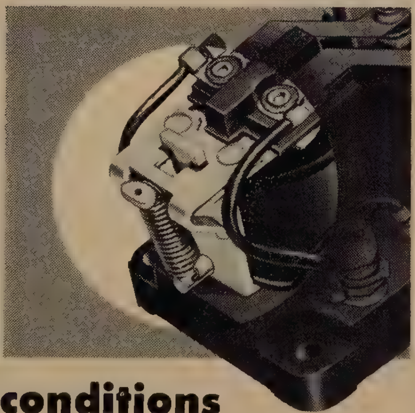
Switches—Factual information concerning Type A, Style A, heavy-duty industrial safety switches includes construction features, application data, extent of line, and horsepower ratings. One section on how to order and specify. Four pages. Bulletin TEC-302A.—*Trumbull Electric Manufacturing Co., Plainville, Conn.*

Telephones—"Sound Powered" titles a catalog describing telephone systems for industrial and mine use, touching on fundamentals, construction, operation, and applications of the Sound Powered principle, and giving the features of station components. Illustrations and wiring diagrams supplement the descriptive text. Eight pages. Catalog 400-A.—*United States Instrument Corp., Summit, New Jersey.*

Thermometers—How to obtain accurate temperature readings between −100 F and +400 F on points up to 1000 ft distant by using Alnor distant-reading electric thermometers. The bulletin enumerates the services for which each type is best suited; gives installation and operation instructions; and lists prices. Eight pages. Bulletin No. 2451-C.—*Illinois Testing Laboratories, Inc., 420 No. LaSalle St., Chicago 10, Ill.*

NEW MIDGET RELAYS

good for all vibration conditions



Ward Leonard's new Bulletin 110 Relays have unusually heavy contact pressures . . . good proportioning of contact masses and springing . . . and semi-knife-edge bearings assuring long trouble-free service under adverse conditions.

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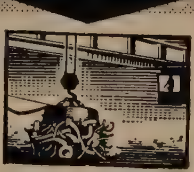

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BOOK REVIEWS

(Available books may be purchased through the GENERAL ELECTRIC REVIEW for domestic delivery; none sent on approval.)

MONOMERS: SECTION I

Edited by E. R. Blout, W. P. Hohenstein, and H. Mark—Interscience Publishers, Inc., New York. 1949. 372 pp. $7.50.

This reference book, constituting a comprehensive collection of data and procedures on the more important vinyl monomers in commercial use today, should be of considerable value to anyone concerned with the preparation of resins, rubbers, and plastics.

While most of the material is available in the literature, location is often a laborious task. The authors have checked discrepancies and determined missing physical constants.

In its present form, the book contains separate chapters describing acrylonitrile, butadiene, isobutylene, isoprene, methyl methacrylate, styrene, vinyl acetate, and vinyl chloride. Additional chapters are in progress and can be conveniently inserted.

Each chapter contains descriptions of laboratory and commercial methods of preparation, methods of purification and analysis, and precautions for the care and handling of the material. The sections on physical properties and the chemical reactions other than polymerization are particularly complete and valuable.

The descriptions of the polymerization techniques, although necessarily limited, would at least seem to be sufficient to serve as adequate background information. A bibliography for each monomer is also included.

The authors have been highly successful in their goal of producing a valuable handbook of information concerning an important class of chemical intermediates.

ROBERT L. MYERS

FOUNDATIONS OF NUCLEAR PHYSICS

Compiled by Robert T. Beyer—Dover Publications, Inc., New York. 1949. 272 pp. $2.95.

Facsimiles of thirteen original papers in nuclear physics are made available here, each in its original format and its original language. The remainder of the book is a bibliography of more than 5000 journal articles in nuclear physics, arranged alphabetically by author under twelve subject headings.

The articles chosen for reproduction are those which have provided the starting point and the stimulus for most of the important areas of research in nuclear physics. The emphasis is well balanced between ideas and concepts on the one hand and experimental techniques on the other. To the modern student these papers should serve as a reminder of the basic simplicity of many of the original ideas and experiments, and as illustrations of the type of reasoning that is characteristic of scientific method.

One may question the justification for such a compilation. After all, every one of the journals represented is a world-known publication, available in any technical library. There seems to be little justification for collecting the papers under one cover unless they are at least translated into English. The pedagogic value of the compilation might have been increased by a brief commentary on each paper, explaining the general scientific situation at the time it was written and showing the evolution and modification of the original ideas by the subsequent development of the field.

The bibliography is a good job and usefully arranged.

HARVEY BROOKS

PRACTICAL ANALYSIS — GRAPHICAL AND NUMERICAL METHODS

F. A. Willers (translated by Robert T. Beyer)—Dover Publications, Inc., New York. 1948. x + 422 pp. $6.00.

With the trend of the past few years in the direction of high-speed machine computation of engineering and scientific problems, there has arisen a need for a textbook on numerical methods of computation pointed toward machine analysis. Unfortunately, a translation of a book more than twenty years old cannot be expected to meet all the requirements for present-day problems.

The material covered here is essentially that found in other standard works on numerical analysis, but with a few variations and with greater emphasis on graphical methods. The chapter headings are: I—Numerical Calculation and Its Aids, which describes slide-rule, nomogram, and desk-type machine calculations; II—Interpolation, with sections on numerical differentiation and integration; III—Approximate Integration and Differentiation, with stress on graphical and planimeter methods; IV—Practical Equation Theory, which contains some material not found in similar texts on a criterion for bounding the complex roots of an equation; V—Analysis of Empirical Function, including harmonic analysis; and VI—Approximate Integration of Ordinary Differential Equations, with graphical, numerical and iterative methods as well as a section on mechanical integrators; the differential analyzer had not yet been developed when this book was written.

F. J. MAGINNISS

A PROFESSIONAL GUIDE FOR JUNIOR ENGINEERS

William E. Wickenden (Edited and collated by G. Ross Henninger)—Engineers' Council for Professional Development, New York. 1949. 55 pp. $1.00.

One of the nicer things in the modern world is the friendly spirit of the young engineers now coming forward as leaders of our postwar technical progress. By and large, these young men are striving to attain a well-rounded development of their inborn powers; to be wise, harmonious, and friendly; to be someone and give something, rather than to win or to get anything. Their constructive interests and participation in civic affairs on a local level are hopeful signs for our future.

One of those who have best foreseen and encouraged this developing professional viewpoint, which after all is in the tradition of "The Sons of Martha" as expressed by Kipling, was the late Dr. William E. Wickenden, President of the AIEE and of Case Institute of Technology.

The guide for junior engineers, with which Dr. Wickenden was engaged at the time of his death, has now been edited by G. Ross Henninger and published by the Engineers' Council for Professional Development. There are nine chapters, starting with the engineer's heritage, continuing with matters of professional practice, registration, civic affairs, and Dr. Wickenden's famous "Second Mile." There are also included a reading list and a most valuable self-appraisal questionnaire.

Every employer or supervisor of engineers should have one of these pamphlets, and every young engineer should read it.

P. L. ALGER

BASIC ELECTRICAL ENGINEERING

George F. Corcoran—John Wiley & Sons, Inc., New York. 1949. vii+449 pp. $4.50.

Written as a college text for a first course in electrical engineering, the mathematics in this book is intended to parallel that given in a concurrent course in calculus.

Subjects covered include: D-c Circuits, Electric Fields, Magnetic Fields, Magnetic Forces, Magnetically Generated Voltages, Ferromagnetic Circuits, Inductance and Capacitance.

The rationalized MKS system of units is used almost exclusively in the text. Field theory is so presented that it can be readily extended to include Laplace's, Poisson's and Maxwell's equations. This treatment of field theory is exceptionally good for the type of course for which it is intended.

The book is well written and should be a valuable text for a beginning course in electrical engineering.

M. D. HORTON

THERMODYNAMIC CHARTS FOR COMBUSTION PROCESSES (Two volumes)

H. C. Hottel, G. C. Williams, and C. N. Satterfield—John Wiley & Sons, Inc., New York. 1949. Vol. I, x + 75 pp., $2.60; II, 31 pp., $2.40.

In well-organized form and carefully substantiated, the authors present thermodynamic charts and tables which will undoubtedly meet their intent. This intent is to provide engineers with a more accurate description of the fuel and air or oxidant mixture in highly useful form to expedite cycle calculations. This work is published in two parts, the second part containing the tables and charts. The text, which is given in the first volume, contains the justification for the authors' selection of data on which the charts are based and for the arrangement and context of the charts.

The value of this work is considerably enhanced by the inclusion of eleven well-chosen illustrative examples of the use of the charts. These examples include piston engine, gas turbine, rocket and ram-jet cycles, making a satisfactory coverage of the field. The omission of the pulse-jet cycle from this series is in keeping with the authors' treatment of the work as a whole in remaining always on well-defined grounds.

There is much splendid rationalizing in this work. A prime example is that involved in the use of $(CH_2)_x$ as the hydrocarbon fuel formula for some of the charts. The authors show that while as wide a variation of fuel composition as represented by octane and benzene yields a minor difference in cycle efficiencies, such a value is a good approximation for most gasolines.

In the text and in the charts there is much useful and time-saving information for the engineers interested in accurate thermodynamic cycle studies.

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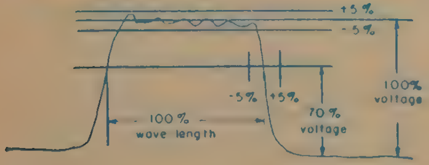

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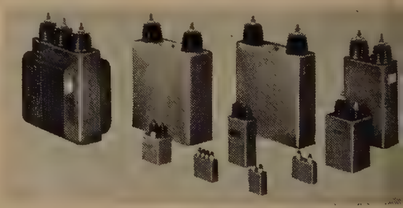

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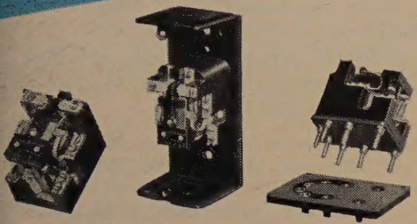

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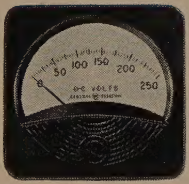

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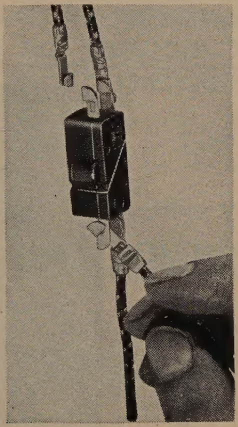

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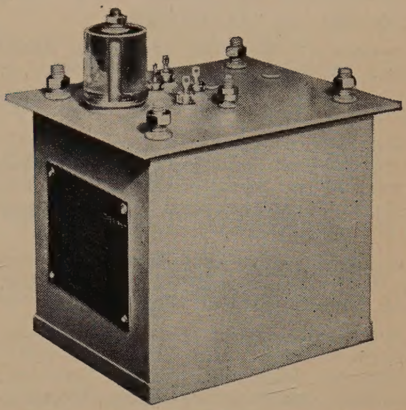

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ON ARTICLES IN OTHER TECHNICAL JOURNALS

AMPLIFIERS, MAGNETIC

BARKHAUSEN NOISE AND MAGNETIC AMPLIFIERS—II: ANALYSIS OF THE NOISE, by J. A. Krumhansl and R. T. Beyer. *Jour. App. Physics*, June 1949; v. 20, pp. 582-586.

The Barkhausen noise is calculated for ferromagnetic cores used in magnetic amplifiers.

ELECTRICAL MACHINERY

VAPORIZATION COOLING OF LARGE ELECTRICAL MACHINES, by Th. De Koning. *Franklin Inst. Jour.*, July 1949; v. 248, pp. 49-68.

Describes a method of cooling considered as revolutionary as hydrogen cooling was in the twenties. A much wider applicability, considerable savings, and other advantages are expected of it.

HANDLEY DESIGN PACES OUTDOOR TREND, by W. F. Friend and C. A. Lilly. *Elec. Wld.*, June 18, 1949; v. 131, pp. 65-68.

Single-unit outdoor station incorporates latest advances in simplification of steam stations. Minimum housing provided; surface condenser in open; electrical design following unit system.

JET PROPULSION

COMBUSTION IN MOVING AIR, by Frank R. Caldwell and others. *Soc. Auto. Engrs. Quar. Trans.*, Apr. 1949; v. 3, pp. 327-340.

Reviews the problems and the progress made in the field of combustion in moving air, and presents some of the results of a five-year program of combustion research. Concerned with combustion as it occurs in jet engines.

TWO-DIMENSIONAL JET MIXING OF A COMPRESSIBLE FLUID, by S. I. Pai. *Jour. Aero. Sci.*, Aug. 1949; v. 16, pp. 463-469.

The mixing and divergence of a supersonic jet exhausting into a supersonic stream are investigated theoretically.

LUBRICATION AND LUBRICANTS

CENTRIFUGAL PURIFICATION OF OILS IN STEEL PLANTS, by Charles M. Ambler. *Iron & St. Engr.*, June 1949; v. 26, pp. 108-116.

The centrifuge as a particularly valuable tool for cleaning and rehabilitating oil when there is a difference in phase or density between the oil and the impurity.

HOW TO TEST BEARING GREASES. *Am. Mach.*, May 19, 1949; v. 93, pp. 102-106.

Thorough tests are made of greases for prelubricated ball bearings before their approval. Methods described here can be applied to grease for other applications.

PROGRESS IN INSTRUMENT LUBRICATION, by Henry Gisser. *Lubrication Engng.*, Aug 1949; v. 5, pp. 175-179, 197.

MEASURING INSTRUMENTS

ABSOLUTE BETA COUNTING, by Benjamin P. Burtt. *Nucleonics*, Aug., 1949; v. 5, pp 28-43.

A study of the procedures of absolute beta counting by means of the end-window Geiger tube.

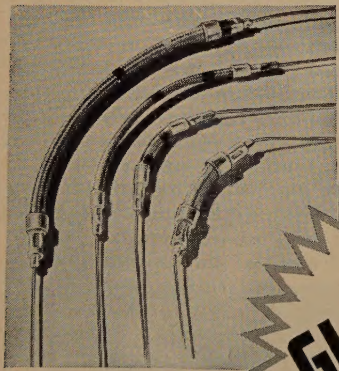
DETERMINATION OF EFFICIENCY OF MICROWAVE, BOLOMETER MOUNTS FROM IMPEDANCE DATA, by David M. Kerns. *Nat. Bur Stds. Jour. Res.*, June 1949; v. 42, pp. 579-585 (RP No. 1995).

Determining the input-to-bolometer-element power-transfer efficiency of bolometer mounts of the type used in microwave power measurements.

METALS

NITROGEN IN STEEL, by Simon Feigenbaum and George H. Enzian. *Iron Age*, June 30 1949; v. 163, pp. 52-54.

Examining the role of nitrogen as a constituent in steel, the author discusses current research trends embracing control and analytical techniques.



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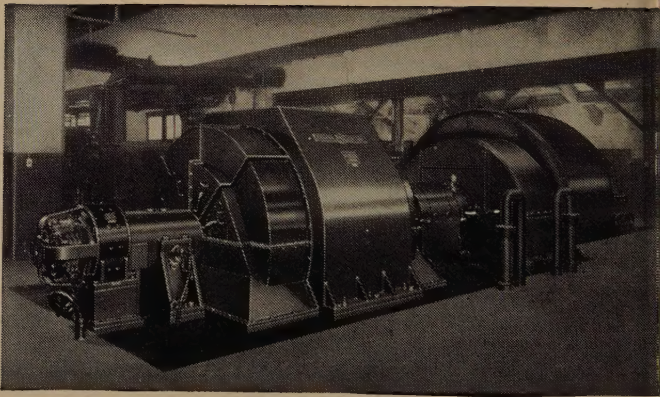

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Ultrasonic Testing of Aircraft Components, by William C. Hitt. *Iron Age*, June 23, 1949; v. 163, pp. 66-70.

Details of the practical work done at one plant, including some interesting variations on ultrasonic equipment usage.

Use of Metals at Low Temperature, by S. L. Hoyt. *Metal Prog.*, June 1949; v. 55, pp. 821-826.

Presents both metallurgical and mechanical factors that enter into the selection of metals for use at low temperature, with emphasis on ferritic steels.

PROCESS CONTROL

Some Application Factors Affecting the Regulation of pH in Industry, by Allen L. Chaplin. *Instruments*, July 1949, pt. I; v. 22, pp. 579-587, 608-610, etc.

The first installment of a serial article on basic principles of automatic control of industrial processes.

RADIO ENGINEERING

General Folded-dipole Antenna Design, by D. L. Waidelich. *Communications*, Apr. 1949; v. 29, pp. 18-20, 30-31.

An analysis of the field patterns and radiation resistance for folded dipoles of any length and with any current distribution in the sides.

Measurement of the Series-resonant Resistance of a Quartz Crystal, by L. A. Rosenthal and T. A. Peterson, Jr. *Rev. of Sci. Instr.*, June 1949; v. 20, pp. 426-429.

Three instruments are described which will measure the equivalent resistance of commercial quartz crystals in the range of 80 kilocycles to 100 megacycles.

STANDARDS

A Suggestion from Switzerland—What About Steel Designations? by H. Abegg. *Standardization*, July 1949; v. 20, pp. 172-174.

A proposed standard system of steel specification designations.

International Screw-thread Standardization, by J. W. Jenkins and K. D. Williams. *Am. Soc. Nav. Engrs. Jour.*, Aug. 1949; v. 61, pp. 531-541.

Summarizes the accomplishments of the joint U.S.–Canadian–British screw-thread commission.

Microwave Measurement Standards. *Radio-Electronic Engng.*, Apr. 1949; v. 12, pp. 3-5, 30.

The frequency range from 300 to 100,000 megacycles and above is covered by electrical standards which are being developed.

WELDING

Effect of "Quench Time" on Weld Metal, by Jay Bland. *Weld. Jour.*, May 1949; v. 28, pp. 216s-226s.

Results of various postwelding quench times on the ductility of all-weld-metal tensile coupons prepared with Type E6011 electrodes are presented, including the effect of a critical quantity of hydrogen.

Several Steel Forms Combined in Heavy-duty Weldments, by Kenneth Rose. *Mat. & Methods*, May 1949; v. 29, pp. 49-51.

Large diesel crankcases built up of steel forgings, plate, tubing, and bar stock have advantages of light weight, lower cost, and longer service life.

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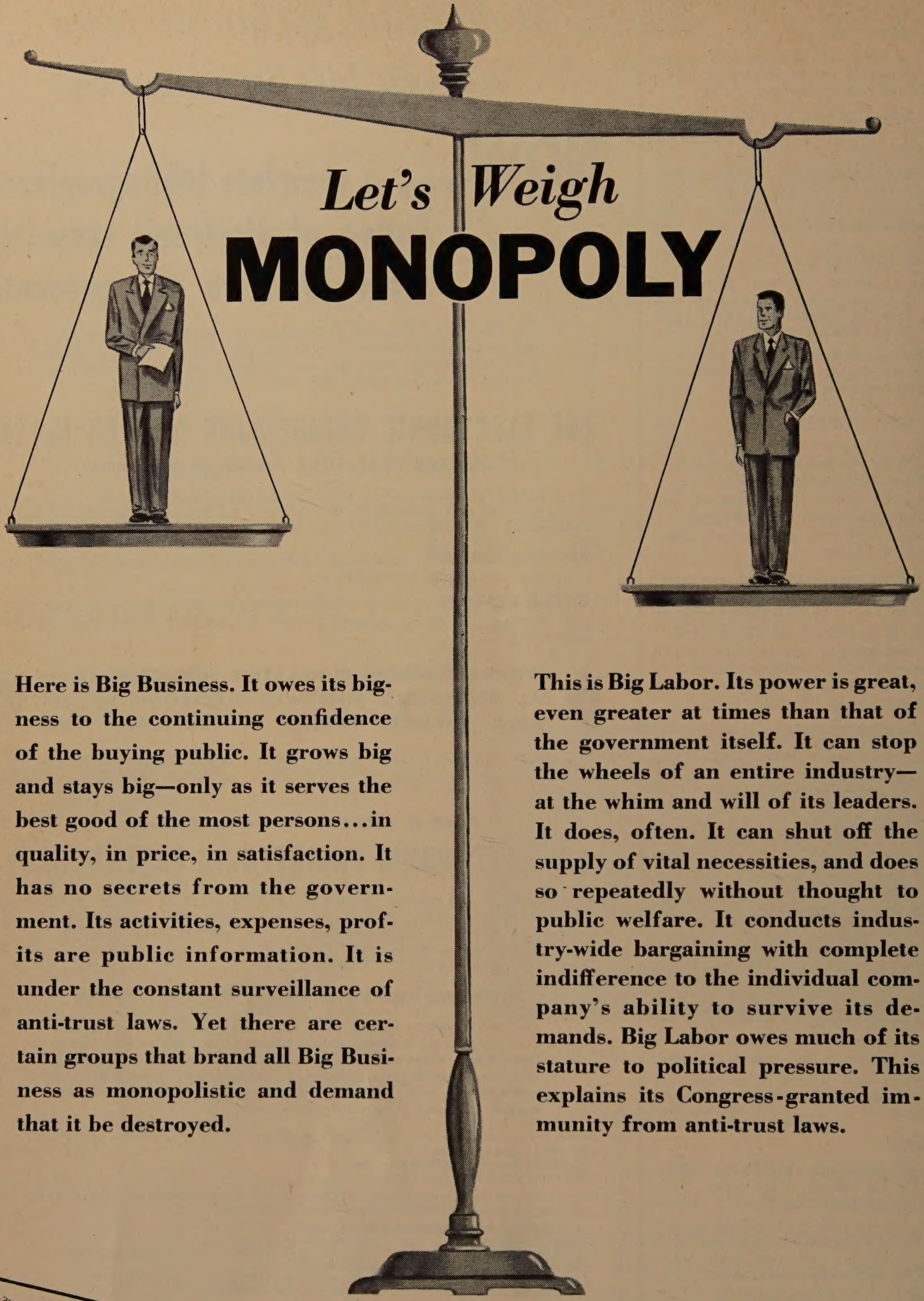

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